No. 226

The Institution of Post Office Electrical Engineers

LOCAL LINES — PAST, PRESENT AND FUTURE

E. C. SWAIN, B.Sc.(Eng.), M.I.E.E.

A Paper read before the London Centre of the Institution on 8th November, 1965, and at other Centres during the Session

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Local Lines — Past, Present and Future

1. INTRODUCTION

Mr. H. R. Huntley in his address to the Conference on Transmission aspects of communication networks held at the I.E.E. in February, 1964, which he entitled "The future arrives one day at a time" said of the future that—

> it arrives continuously, day by day, and as it arrives, the way it looks constantly changes.
>
> That is, the past and future form a continuum along which the present moves; there are constant changes in direction but the sheer size and longevity of the plant and of the investment in it, prevents discontinuities.
>
> The wise planner, therefore, follows Sir Winston Churchill's advice that "he who looks back the farthest can look ahead the best", and does something like this:
>
> He examines past and current history to find those social, economic and technological trends which point to the general direction in which he should be going.
>
> Then, since he knows that the only constant thing about the future is change, he makes *flexibility* a basic factor in his planning.
>
> And he always makes the most effective use of the plant he has and of what is currently available in the way of new things to promote service improvements, economy and flexibility. And he forces technology to use the fruits of science (old and new) to produce the new tools he needs.

It was in 1945 that Mr. Harvey Smith recommended and the Engineer-in-Chief agreed to the introduction of a "new system" for the provision of plant in the local line network. The object of this paper is to review progress made in the introduction of the "new system", to assess the present position and hence look forward for the next 20 years and beyond.

2. SUMMARY OF THE CONCLUSIONS AND RECOMMENDATIONS OF MR. HARVEY SMITH'S REPORT

2.1 The Report criticised the pre-1939 plant provision practice in that it failed adequately to cater for the demands for service, due largely to the lack of provision to meet unexpected growth, to periodic restriction of expenditure and to changes in plant provision policy. It envisaged that a continuation of the method of provision would lead to an increase in the spare wire margin and the annual cost of a subscriber's line. It foresaw that changes in the various post-war plans of national and local administration would increase the difficulties in assessing future telephone development and great inaccuracies must be allowed for in plant provision necessitating a much higher degree of flexibility than could be obtained under the practice then existing.

2.2 Flexibility at that time was obtained mainly from the use of 'multiple-teeing' or 'auxiliary joints' together with a number of 'cable distribution heads' used in congested city areas.

In the multiple-teeing system a proportion of the cable pairs from the Main Distribution Frame (MDF) are teed together at joints and so are connected to more than one Distribution Point (DP). This system uses what is termed "non-tapered cable", that is, the main cable does not reduce in size at every spur junction point. In a fully multiple-teed system as employed in the USA the reduction in size of the main cable usually occurs at points where its size can be halved.

The object of the auxiliary joint method is that having connected the 'permanent' pairs from MDF to DP through a 'permanent' joint, a proportion of the pairs are connected via an auxiliary joint (originally a plumbed joint but later a mechanical one) where any alterations in requirements can be made subsequently. The disadvantage of this arrangement was that it was found that due to changes in the growth pattern more often than not alterations had to be made in the permanent joint or between the MDF and the DP.

The 'cable distribution head' was a large cast-iron box into which paper-insulated lead-sheathed cables were led through water-tight glands (Fig. 1). Wire

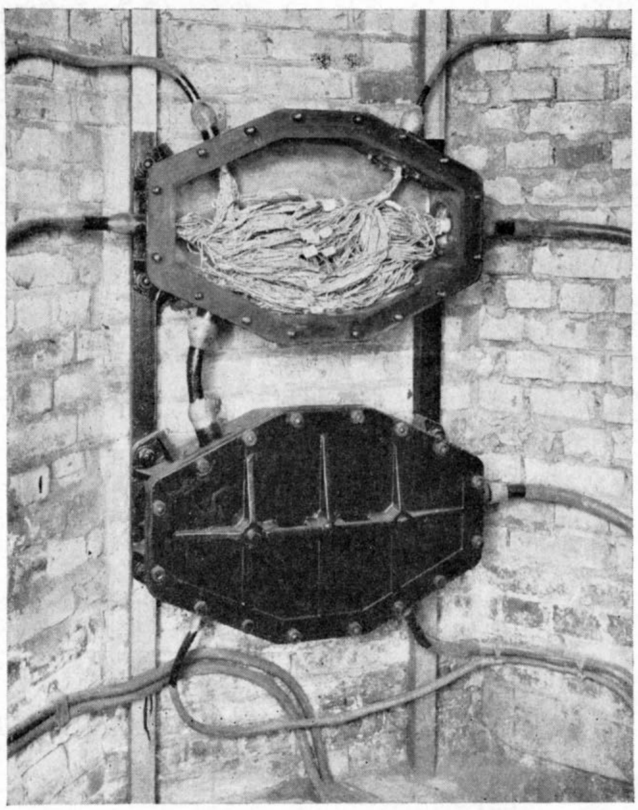

FIGURE 1—CABLE DISTRIBUTION HEAD

joints were made by the normal twist method. In theory, full flexibility was provided since any pair could be jointed to any other pair in any cable led into the 'head'. In practice, as development proceeded and many wire joints had been broken down and re-made, the 'head' became a conglomeration of copper and paper thus creating a considerable maintenance hazard not helped at all by the difficulty in maintaining suitable and accurate records.

It is reported that in 1944 only about 20 per cent of the necessary flexibility which should have been provided to give full flexibility over the whole network had actually been installed.(1)

2.3 The system recommended for post-war application was a combination of the Ericsson cabinet system, the Australian pillar system and the American multipling system so devised that the principal advantages of these systems were obtained without the full acceptance of their disadvantages. A diagram of the proposed system, already familiar to most people, is shown in Fig. **2.** It was claimed that the new system would save about £225,000 per annum (£675,000 at present-day prices) and that reduction in the spare wire percentage and cable pair re-arrangements would occur. Facilities for routing private wires and extensions, for conversion from overhead to underground and for potential party line services would be available with simplified planning and construction.

2.4 The introduction of the system was recommended in two stages : (*a*) the insertion of cross-connexion cabinets and pillars on the existing tapered cable systems, and (*b*) the provision of non-tapered multiple-teed cables for new growth. New cables should be of the "unit" type and the use of layered quad cables should be discontinued. The Report stated that the cable provisioning periods under the new system would be considerably shorter than in former practice, so conserving capital expenditure in the early post-war period, spreading it more evenly over future years and enabling full advantage to be taken of technical improvements. It further recommended that the provision of ducts should be on a more liberal scale, greater attention should be given to future overhead line provision to give improved appearance and thus minimise possible objections, covered drop wire should not be used in residential areas and greater use should be made of ring type DPs.

(1) *See end of paper for references*

(*Author's note.* The terms "cabinet" and "pillar" are now used loosely. In fact, what is intended is the contents of the cabinet or pillar and therefore the correct term is "cross-connexion cabinet" and "cross-connexion pillar". The word "assembly", that is, the cross-connexion arrangement should also be "cross-connexion assembly". However, in this paper it is proposed to continue to use the shorter terms.)

3. EXPERIENCE WITH THE PROPOSED SYSTEM OVER THE PAST 20 YEARS

The sub-paragraph headings have been arranged to cover most of the matters in the order mentioned in Mr. Harvey Smith's report.

3.1 Growth of the System

The proposed system was introduced into the local line network early in the post-war years and it has gradually expanded, so that 70 per cent of the main cable pairs are now connected to cabinets and pillars.

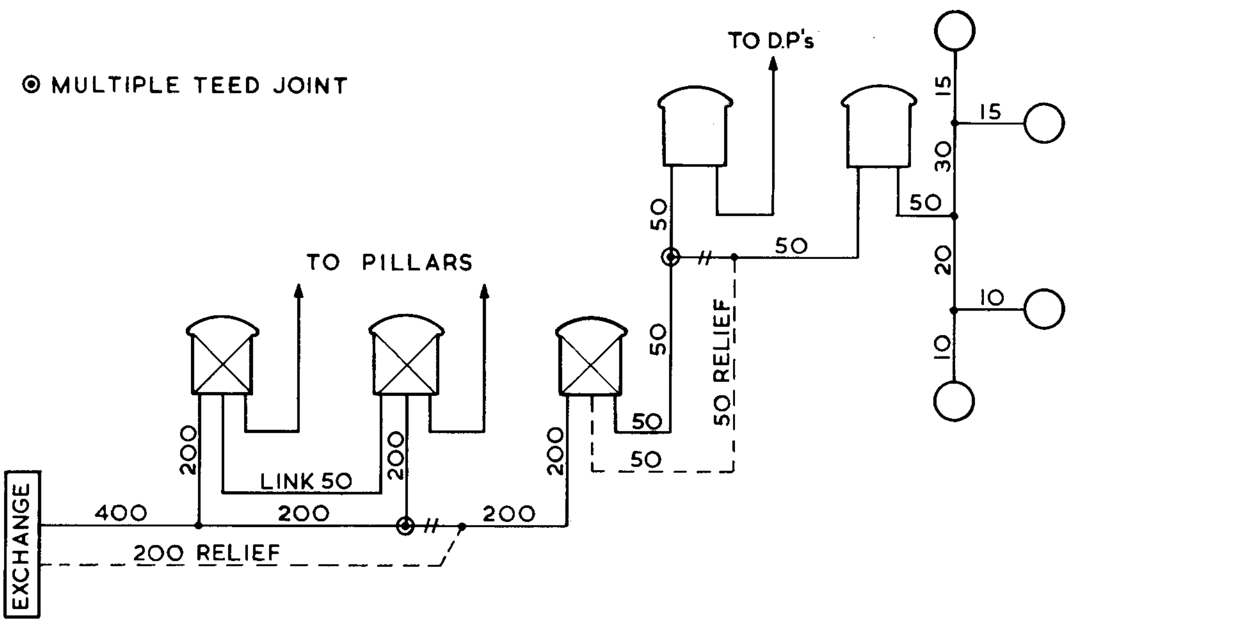

FIGURE 2—LOCAL LINE NETWORK AS PROPOSED BY MR. HARVEY SMITH

Fig. 3 shows the growth in the number of cabinets and pillars installed and Fig. 4 shows the growth in the percentage of main cable pairs connected via cabinets or pillars.

Cabinets and pillars were inserted on the existing cable networks and relief tapered cable networks generally have been provided. The use of non-tapered multiple-teed cables has found little favour due to jointing and recording complications for marginal economic savings.

It is relevant at this point in the paper to consider how the forecast of exchange connexions has changed in the past 20 years. This is illustrated in Fig. **5.** Mr. Harvey Smith had forecast 5,100,000 exchange connexions in 1960. In the event, the number of exchange connexions at March, 1960, was 4,784,000 and the number of line waiters was 44,000.

3.2 Flexibility

The cross-connexion assembly arrangement as adopted provides for full flexibility i.e. any pair on the exchange or 'E' side can be cross connected to any pair on the distribution or 'D' side. The cross connexion is achieved by 'pins' or 'jumpers'. Furthermore, it is the usual practice for every distribution pair in the territory served by the flexibility point to be terminated on an assembly. Partial flexibility, i.e. some pairs connected via the flexibility point and some connected directly to the exchange, was not recommended in the new system and has not been adopted. As already mentioned in paragraph 2.2 the disadvantages of partial flexibility had become apparent in the use of auxiliary joints.

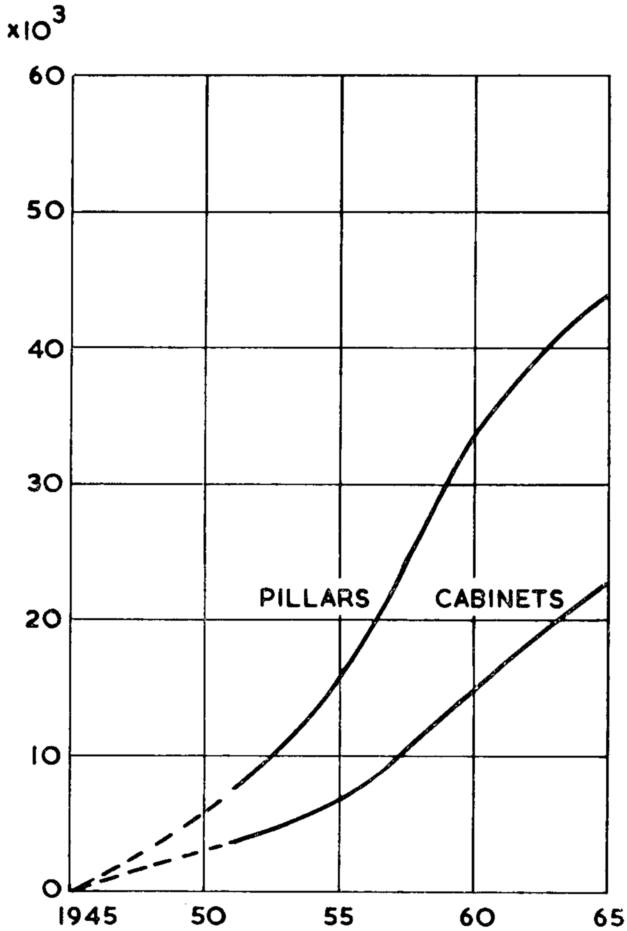

FIGURE 3—NUMBER OF CABINETS AND PILLARS

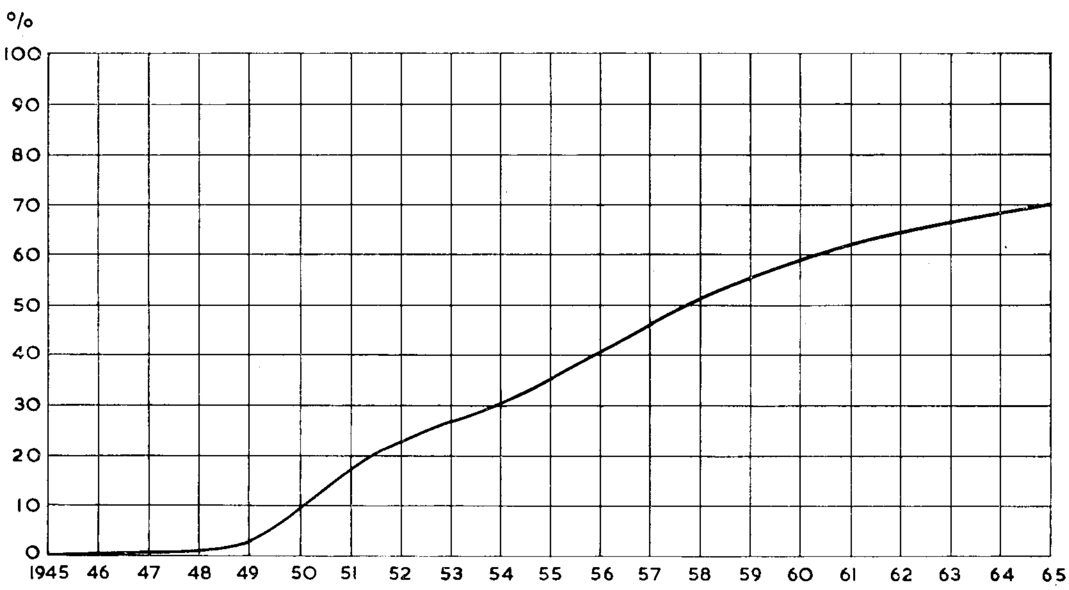

FIGURE 4—PERCENTAGE OF MAIN CABLE PAIRS CONNECTED VIA CABINETS AND PILLARS

An advantage of full flexibility which has been achieved is that main cables can be used to maximum fill before relief has to be provided. This facility is particularly useful in territory which has reached a fair level of penetration and a slow rate of growth. The many removals and transfers which occur in this type of territory can be dealt with by changes of pins or jumpers. A further advantage of the cabinet and pillar system is the simplicity in the jointing arrangement when providing relief cables which are terminated at both ends.

There is often confusion between the three different although related terms "minimum spares", "planning cable fill" and "actual cable fill".

The term "minimum spares", as related to a cabinet, pillar or DP is fixed arbitrarily at approximately 15 per cent. It is used to direct the attention of the planning engineer to those places where relief might be necessary. Each case must then be considered on its merits to decide whether or not immediate relief is required.

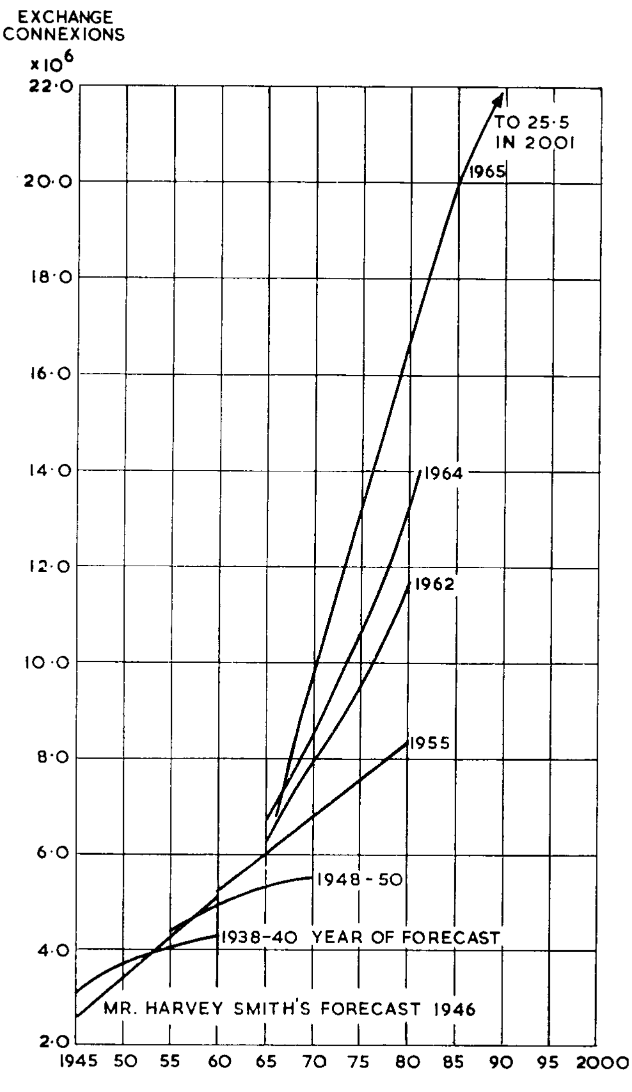

FIGURE 5—TOTAL FORECAST OF EXCHANGE CONNEXIONS

In order to allow for fluctuations in actual growth(2), when planning to provide a new or relief cable to a cabinet, pillar or DP, the pair requirements are determined by dividing the forecast of exchange connexions and miscellaneous circuits by the "planning cable fill". This has the effect that when the achievement actually reaches the forecast, the percentage number of cable pairs working will be equal to the planning cable fill percentage. Planning cable fill refers only to planned conditions.

"Actual cable fill" is usually expressed as the percentage of working pairs over total pairs.

The existence of full flexibility has undoubtedly made possible the deferment of expenditure on main cables at times when there have been restrictions on capital expenditure. The main disadvantage has been the difficulty of maintenance of the assemblies and pins and jumpers. Much of the earlier difficulties due to low insulation in the cable 'tails' have been overcome by the use of polythene insulation but unfortunately there are thousands of assemblies in use with paper-core cable 'tails'. Difficulties have also arisen from pins and jumpers becoming loose but tests have proved that properly installed pins and jumpers remain firmly secure.

In spite of this disadvantage the decision to adopt full flexibility with two flexibility points in tandem has been fully justified in the conditions which have existed over the past 20 years. Only one major error has been made. In general, cabinet and pillar shells have not been large enough or alternatively have been provided to cover too large areas. The lesson for the next 20 years is to make sure if possible that termination space is provided in every cabinet for all cable pairs likely to be required in the territory to be served. This matter is further discussed in paragraph 7.1.4.

3.3 Spare wire percentage

The total pairs (i.e. cable pairs terminated on the MDF and connected to cabinets, pillars or DPs), spare pairs and the percentage spare pairs for the years **1945-65** have been shown in Fig. **6.** Prior to the **1939-45** war the percentage spare pairs had fallen from **43** per cent in **1934** to **33** per cent in **1938.** During the war period the percentage spares rose to **38** per cent in **1942** and fell again to **33** per cent in **1945.** The spare pair position has been affected more by the demand and the available effort to expand the system and by shared service than by the introduction of cabinets and pillars. Thus there is not much evidence on which to substantiate the claim that the new system would reduce the spare wire percentage.

However, it has been estimated that without cabinets and pillars and in order to provide the same pair availability as exists at present at all DPs, an additional **2,700,000** pairs would have been required, thus increasing the spare pair percentage to **46** per cent. The present system has undoubtedly resulted in a smaller spare wire percentage than if the system had not been introduced.

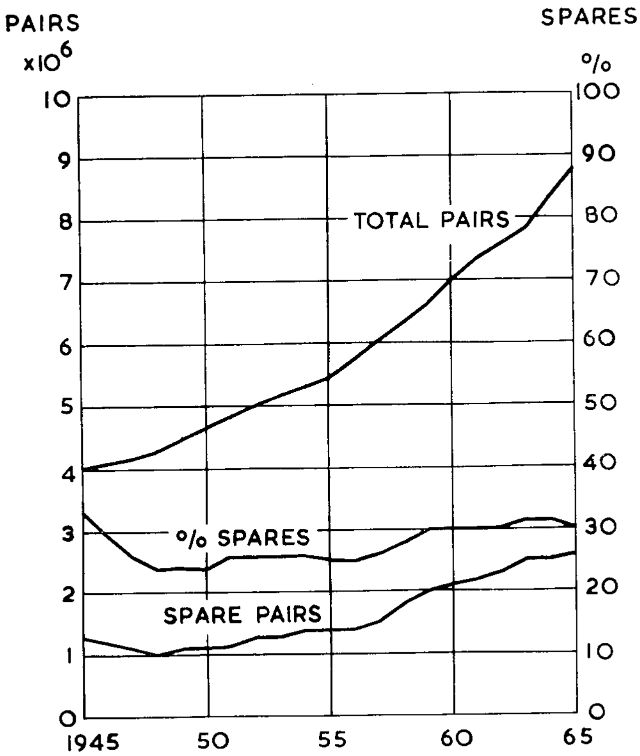

FIGURE 6—TOTAL AND SPARE PAIRS MDF TO CABINETS, PILLARS AND DP'S

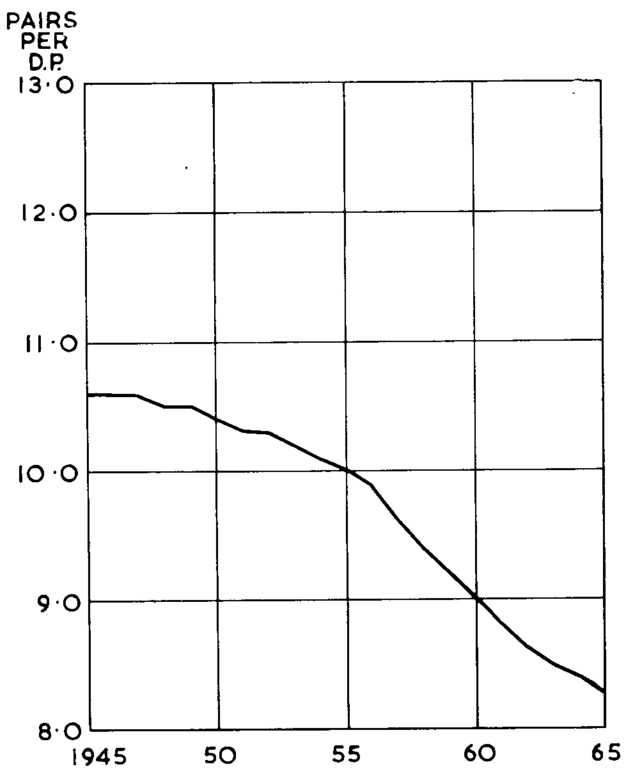

FIGURE 7—MAIN CABLE PAIRS PER DP

It will be seen from Fig. **7** that there has been a continual fall in the number of main cable pairs per DP thus indicating more efficient use of main cables and at the same time making the pairs available over a large geographical area.

3.4 Cable pair re-arrangements

Any great cost savings arising from a reduction in cable pair re-arrangements over the past 20 years have largely been masked by the re-arrangement work involved in introducing cabinets and pillars into the network. However, it can be seen from Fig. **8** which shows the manhours spent on local cable shifting work per added pair since **1948** that there has been a reduction from 25 to 6 manhours.

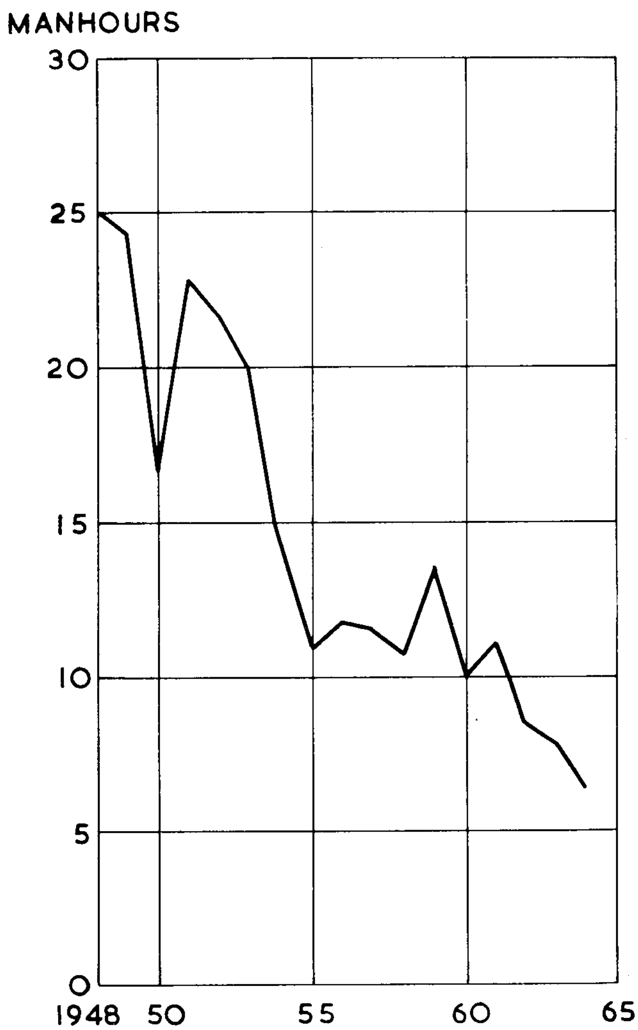

FIGURE 8—DEVELOPMENT WORK—MANHOURS ON SHIFTING PER ADDED PAIR

Fig. 9 shows the manhours spent on shifting work on subscribers cables per exchange connexion supplied since 1950. It will be seen that the value has fluctuated about 2 manhours and there has been no significant reduction. This means that pairs are still being shifted to complete the connexion between the exchange and the subscribers premises. If the manhours spent on shifting are being incurred in making pin and jumper changes at cabinets or pillars then the system is meeting its basic function ; if, however, the manhours are being spent in changing over pairs in cables then the system is failing. Probably both conditions exist.

The great reduction in shifting costs which has been achieved was one of the main benefits which was expected to accrue from the introduction of cabinets and pillars.

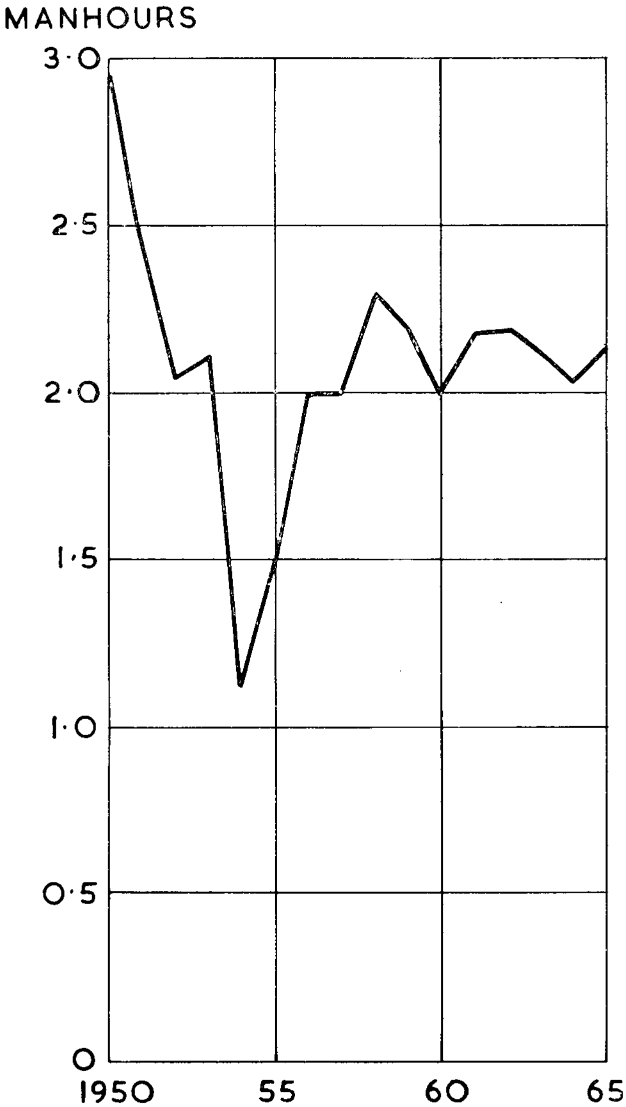

FIGURE 9 —SUBSCRIBERS SERVICES—MANHOURS ON SHIFTING, PER CONNEXION SUPPLIED

3.5 Routing of external extensions

It was claimed that the availability of cabinets and pillars would enable local routing of external extensions and private circuits to be achieved more easily. No statistical evidence that the system has assisted in this respect is available but it is known that in many industrial estates considerable use is made of link cables between cabinets for routing external extensions.

3.6 Reduction in jointing chamber operations

The claim here was that the use of cabinets and pillars would reduce the work required at jointing chambers and hence avoid long periods of shift work at specific points. Again the experience is that whilst cabinets and pillars have been in process of being installed probably more jointing work has been necessary than heretofore. However, the stage is rapidly being reached when there will be few points where long periods of time will be required on jointing work.

3.7 Simplicity in planning relief measures

Simplicity in planning and providing relief cables is one of the major advantages of the cabinet and pillar system and where most benefit is now being felt from the work of installing cabinets and pillars over the past 20 years. The day of the full scale relief scheme to a complete or large part of an exchange area is past. The network is now divided into distinct sections and work in each section can be planned and go on independently of the other sections. Economic provisioning periods based on growth and planning cable fill can be applied to each section so that the maximum economic advantage is obtained.

Main cable relief is generally restricted to the cabinets on a cable route requiring relief within four years. Seldom is relief necessary to the entire cable route and may often be limited to a single cabinet. Relief in the distribution section and the provision of new plant to new distribution areas can be carried out independently of main cable relief.

There are other factors involved, but the reduction in the cost per added pair from £35·3 in 1953 to £31·2 in 1964 (actual costs) or from £54·8 in 1953 to £32·4 in 1964 (at present day prices) indicates that the service is reaping considerable benefit from the introduction of cabinets and pillars.

A return taken in 1964 of actual direct costs of the provision of relief cable pairs from exchange MDFs to cabinets in various parts of the country shows that 35,000 pairs were provided at a cost of £9·3 per pair (made up of £2·2 for duct and £7·1 for cable).

3.8 Simplicity in jointing

The claim that unit type cable would simplify planning and jointing work has been fully justified. The facility of having cable pairs in units of 50 and 100 pairs considerably simplifies jointing work compared with a layered quad type of cable.

3.9 Simplicity in plant records

The advantages of the new system from a record point of view have mainly accrued from the division of the network into sections so that plant records of each section can be compiled separately.

The cable pair allocation record was however made unnecessarily complicated. The conception of a separate record for each of the three sections of the network as in trunk and junction cable practice was quite correct but the forms used for the record were confusing and misleading. The fundamental error made was that the record must be read from left to right (i.e. from the DP on the left to pillar, cabinet or MDF on the right). But in fact on an assembly the E side pairs appear on the left and the D side on the right. This is confusing and led to the need for further forms for use as cabinet and pillar design schedules.

New records have now been devised which require a circuit to be routed from the DP on the right to the MDF on the left. The new combined Cabinet and Pillar Card and the new DP card are now being used experimentally at many offices throughout the country. There is no need for the cabinet record and pillar design schedules because the new form can be used instead. As would be expected, the introduction of these new forms has created other complications but these are being overcome and it is hoped that the new forms will be in use all over the country within 2 to 3 years. Further savings in planning and execution time are expected on re-arrangement work by extending the new forms to show both the old and the new conditions and so avoid the need for a jointing or diversion schedule. The use of the new forms coupled with photocopying machines to produce field copies of records should result in much simplification of record work at the planning and completion stage of development.

4. IMPROVED TECHNIQUES IN THE DESIGN, PROVISION AND UTILISATION OF EXTERNAL PLANT

The past 20 years have shown major advances in the design, provision and utilisation of local line plant, a few of which are mentioned in the following paragraphs.

4.1 Ducts and jointing points

Improvements in these have been fully described recently[3] and therefore need no further description except perhaps to mention that many local distribution cables are now being laid directly in the ground either by trenching or by mole plough.

4.2 Cables

The development of plastic sheath and plastic insulation for cables has considerably reduced the cost of the provision of pairs in both aerial and underground cables.[4][5][6][7] It led to the design of the self-supporting aerial cable with the suspension wire and cable pairs moulded in the same 'figure of eight' sheath, so avoiding the need to erect a separate suspension wire and for a cable lashing machine. The adoption of polythene in place of lead for the sheath of underground cables has enabled much longer lengths of cable to be manhandled and pulled into ducts than heretofore.

The type of cable used is largely decided on economic grounds and the present standard practice is for cables up to 100 pairs to have polythene insulation and a polythene sheath. Cables greater than 100 pairs generally utilise paper insulation and a polythene sheath incorporating a 3 mil aluminium foil acting as a water barrier. Polythene insulated and sheathed cables over 100 pairs in the same sizes as the paper insulated cables are now used for direct termination on the MDF thus considerably simplifying the jointing arrangements in cable chambers. It is often economic to use polythene insulated cable from the MDF through the cable chamber and the exchange manhole to a jointing point some distance away in the network thus avoiding congestion of joints and jointing work in the exchange manhole, cable chamber and/or trench.

4.3 Overhead distribution

The greater use of ring type DPs was recommended by Mr. Harvey Smith although the use of drop wire was not advocated. The more recent introduction of a pvc insulated copper-plated steel wire type of drop wire (Cable, Drop Wire No.3) and self-supporting pvc sheathed polythene insulated aerial cable in many sizes down to 4 pairs will virtually eliminate the use of open wires for overhead construction in future. The savings in construction and maintenance costs should be very great. However, the use of drop wire and aerial cable in place of open wire will in some instances necessitate the use of heavier gauge conductors in the underground cables feeding the DP's so connected in order to meet transmission and signalling requirements.

4.4 Flexibility points

Improvements in the design and utilisation of cabinets, pillars and assemblies have taken place during the past 20 years[8][9]. The earlier 'open' type assemblies on which each 'pin' or 'jumper' was connected to an exposed screw terminal have been replaced by the now familiar "closed" type of assembly in which one pressure screw is used to secure two wires. The enclosed type of assembly caters for twice as many circuits in the same space as an open type assembly.

More recently the width of the assembly has been reduced by ½ inch by removing the centre spacing block. The use of the narrower assembly has enabled the pillar to be modified to cater for twice as many circuits as the largest earlier type (i.e. 200+200 in place of 100+100) and provided more space for jumpers in cabinets.

The advent of plastic insulated cable has simplified the termination and sealing of the cables on the back of the assembly and has largely eliminated the difficulties due to low insulation of the paper insulated cables at this point (see also paragraph 3.2).

4.5 Mechanical aids

Investigations are continually being carried out into methods of reducing the labour involved in the provision of external plant. Recently developments such as the line construction vehicle[10] and the duct motor No. 1[11] will no doubt show considerable savings in the future.

4.6 Transmission

The introduction of the modern telephone (the 700 type) with its increased sensitivity has resulted in the reduction in size of the cable conductor. Whereas the normal conductor sizes used to be 6½, 10, 20 and occasionally 40 lb/mile, the present transmission and signalling requirements can be met by using 2½, 4, 6½, 10 and occasionally 20 lb/mile conductors.

Any further reduction in conductor size is governed by the ability to handle the finer wire. A 2½ lb/mile conductor of 0·0126 inches diameter is probably the smallest conductor which can be insulated and jointed by traditional means but smaller wires may be in use before the expiry of another 20 years.

It has been found necessary to load some subscriber circuits which are very long and at present 88 mH ferrite coils built into joints at 1500 yards spacing are being used (mostly in 20 lb/mile cable). The present rate of installation is less than 100 loaded circuits per year.

5. PRESENT POSITION

5.1 In situ plant

The local line network is a vast network and consists of some 1 million distribution points, 5 million poles, 1 million single wire miles of overhead wire, 100,000 way miles of duct and 9 million loop miles of cable.

The Exchange Line Costing Study is being carried out at the present time to obtain more information on the details of the in situ plant[12]. Detailed surveys are made of the plant used by exchange connexions, which are selected statistically according to their radial mileage from a large random sample of exchange connexions.

The processing of the information obtained on the surveys takes a considerable time and most of the information given in the following paragraphs has been derived from the first two years of the study.

The average route and radial distances of an exchange connexion are 1·053 miles and 0·745 miles respectively, giving an average ratio of 1·414 to 1. Fig. **10** illustrates the distribution of exchange connexions with radial distance while Fig. **11** shows the difference between the business and residential categories. Fig. **12** illustrates the relationship between route and radial distances. Fig. **13** shows the relationship between route and radial distances of overhead and underground plant excluding the subscribers service. It can be seen that the route length of the overhead plant is fairly constant up to 0·9 miles radial distance only varying between 25 and 60 yards, whilst the route length of the underground plant rises linearly up to 1·2 miles radial and then tends to flatten out.

Fig. **14** shows the cumulative percentage connexions and exchanges for various multiple sizes of exchanges. It can be seen that 80 per cent of exchanges, i.e. under 1000 multiple, are responsible for only 20 per cent of the connexions, in other words 80 per cent of exchange connexions are in 20 per cent of exchange areas.

The capital assets have a replacement value of approximately £730 millions and the percentages of

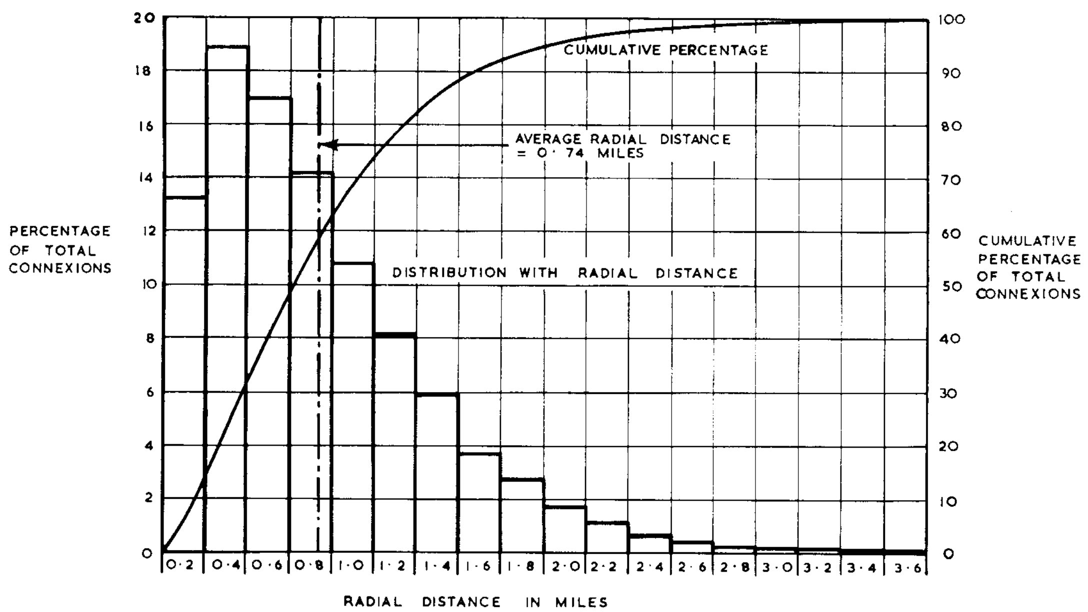

FIGURE **10**—DISTRIBUTION OF EXCHANGE CONNEXIONS

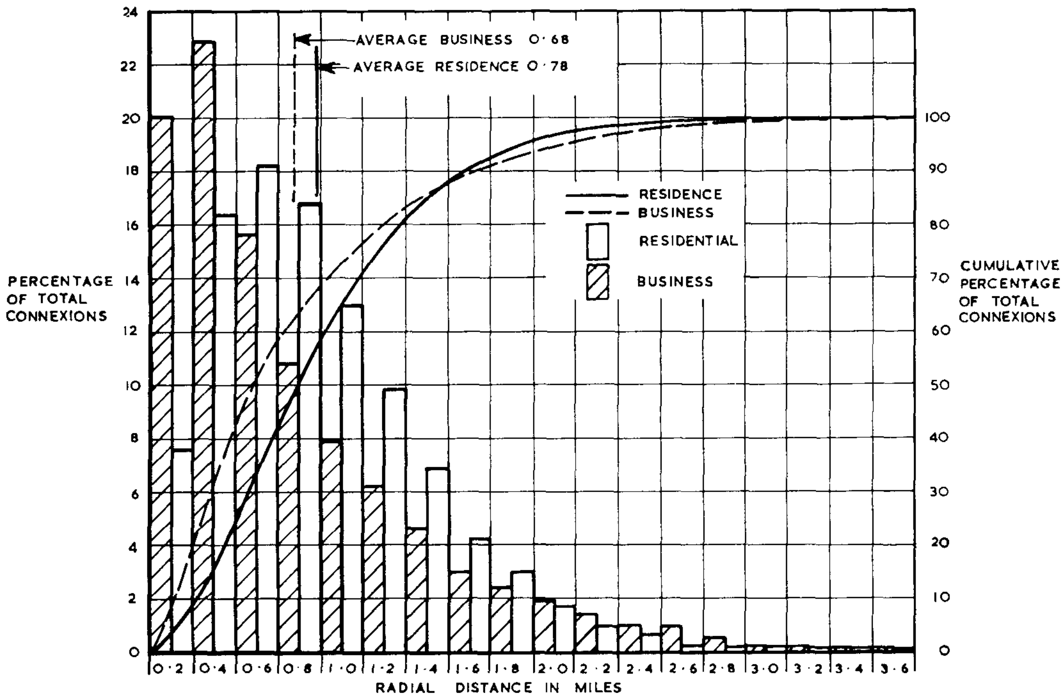

FIGURE 11—DISTRIBUTION OF EXCHANGE CONNEXIONS — RESIDENCE AND BUSINESS

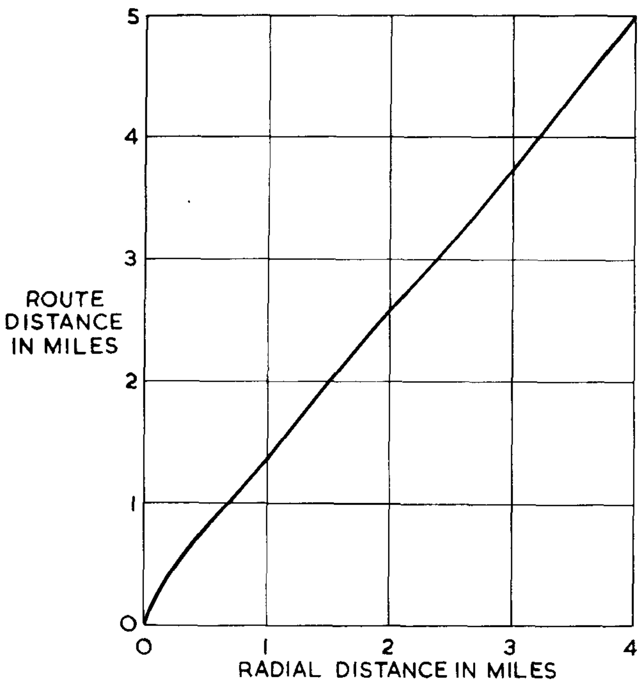

FIGURE 12—RELATIONSHIP BETWEEN ROUTE AND RADIAL DISTANCE

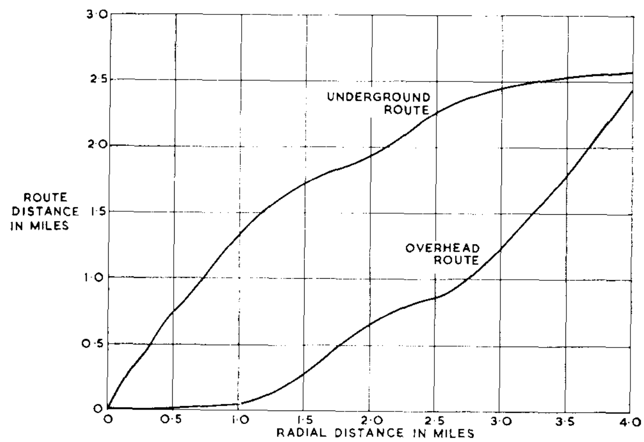

FIGURE 13—RELATIONSHIP BETWEEN OVERHEAD AND UNDERGROUND ROUTE AND RADIAL DISTANCE (EXCLUDING SERVICE)

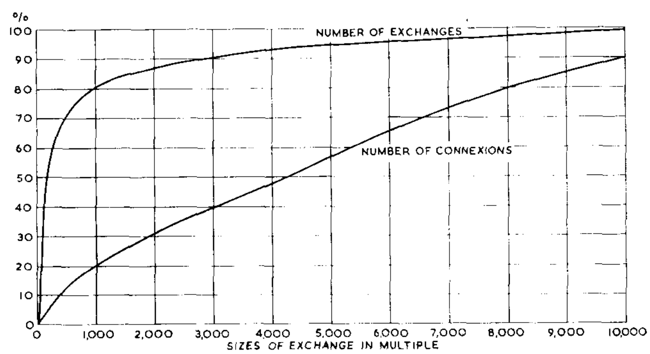

FIGURE 14—CUMULATIVE PERCENTAGE CONNEXIONS AND EXCHANGES FOR VARIOUS MULTIPLE SIZES OF EXCHANGES

these assets are shown in Table I. Fig. **15** illustrates the relationship between the cumulative percentage and radial distance. It can be seen that 90 per cent of the exchange connexions, i.e. up to 1.5 miles radial, are responsible for 74 per cent of the assets. Furthermore since 80 per cent of exchange connexions are in 20 per cent of the exchange areas, approximately 60 per cent of the assets are involved in the provision of exchange connexions up to 1½ miles in only 20 per cent of exchanges.

TABLE 1

Percentages of Capital Assets

	%
Duct and jointing points	45
Underground cable	26
Cabinets and pillars	2
Overhead wire, poles and aerial cable	19
Services	8

Fig. **16** illustrates the distribution of capital assets with radial distance of exchange connexions and it can be seen that the maximum capital asset is incurred in the provision of connexions at approximately 0.5 miles.

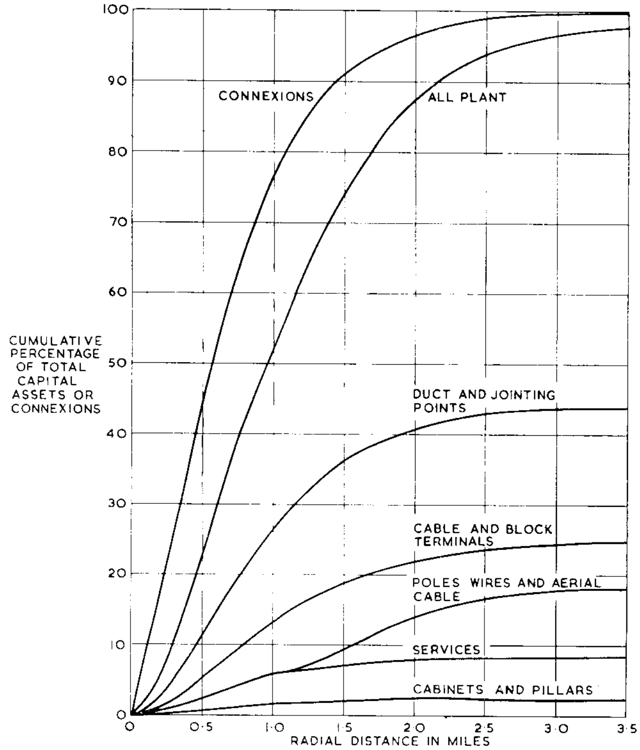

FIGURE **15** CUMULATIVE CAPITAL ASSETS WITH RADIAL DISTANCE

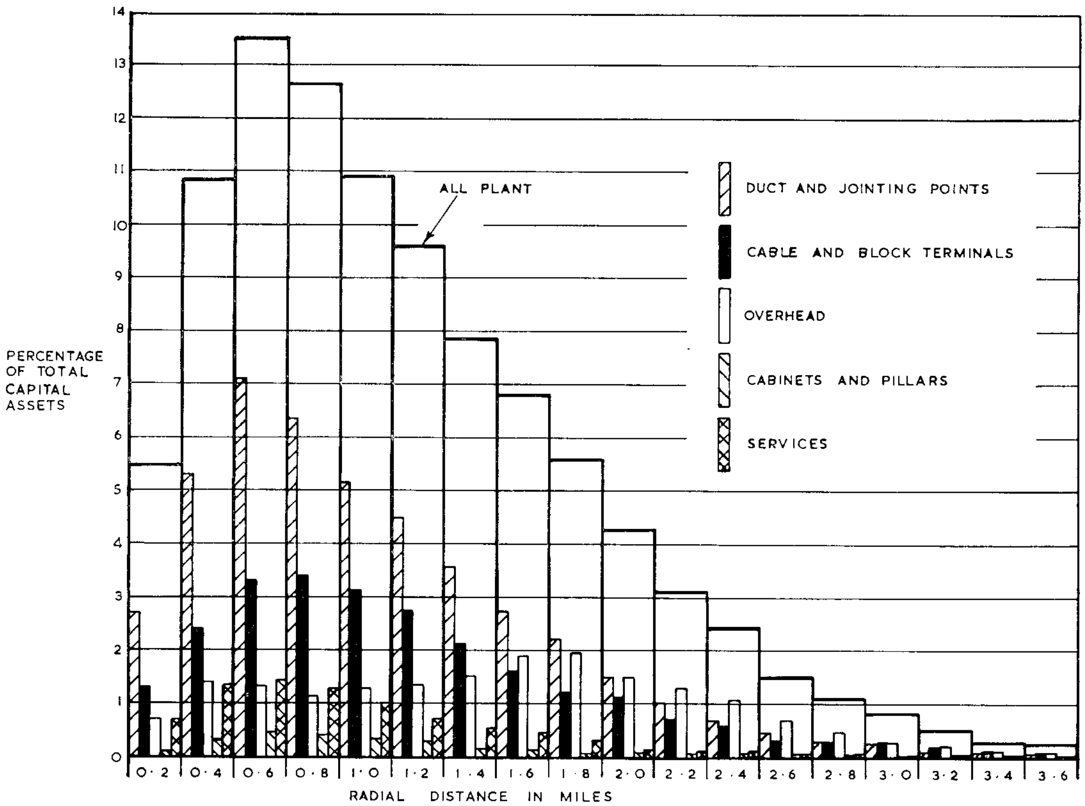

FIGURE **16**—DISTRIBUTION OF CAPITAL ASSETS WITH RADIAL DISTANCE

5.2 Achievement in the past 20 years

One of the chief aims of the new system recommended for adoption in 1945 was flexibility to meet fluctuations and deviations in forecast and yet paradoxically the main difficulty in the past 20 years has been just that. However, the real difficulty has arisen from the inadequacy of the *total* forecast rather than the distribution of the forecast. Each successive revision of the forecast has been upward and so far the 20 year figure has in the event been grossly exceeded. This is clearly illustrated in Fig. **5**.

Nevertheless, in spite of the rapid growth and fluctuations in finances over the 20 years the network has been expanded and service given to an additional 3,800,000 exchange connexions. The number of pairs added in the same period is 4,800,000. The applicants waiting for line plant have been reduced from 360,000 in 1949 to 23,000 at June 1965, and at present 88 per cent of applications can be provided with service on demand.

All this is no mean achievement during 20 difficult years.

Figs. **17**, **18** and **19** show annual demand, direct expenditure (at 1946/47 price levels) and applicants waiting for line plant.

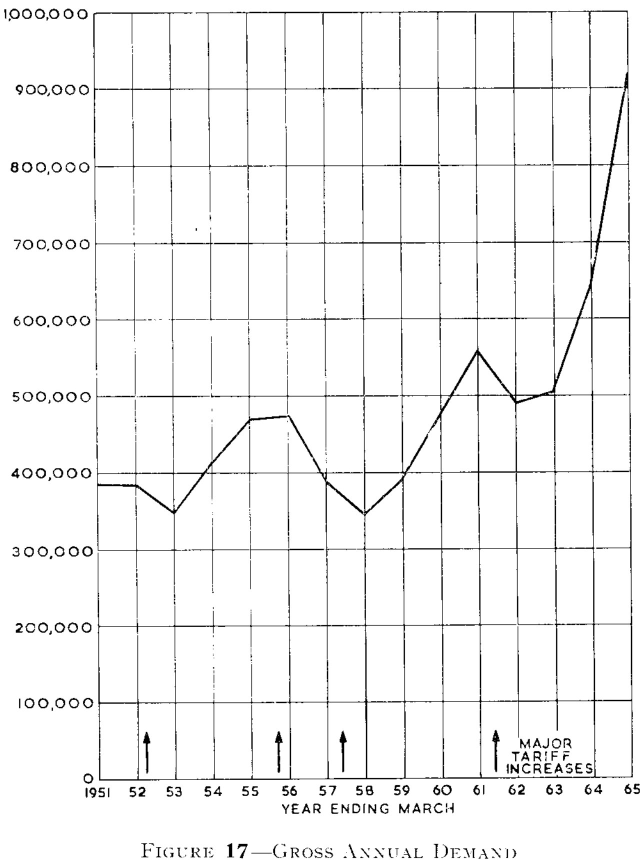

FIGURE **17**—GROSS ANNUAL DEMAND

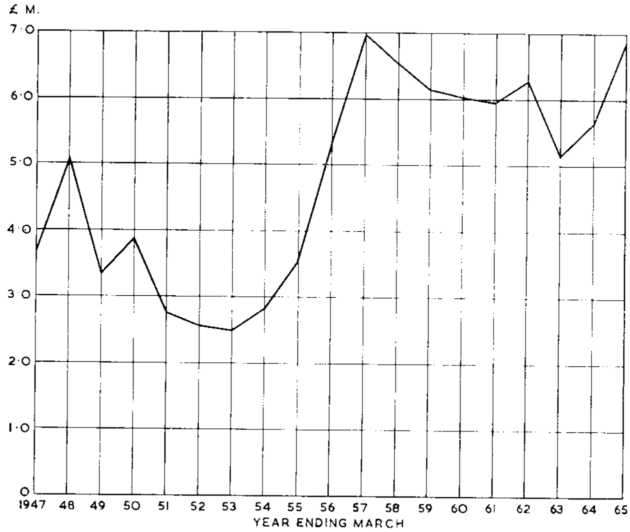

FIGURE **18**—CL EXPENDITURE AT 1946/47 PRICE LEVELS

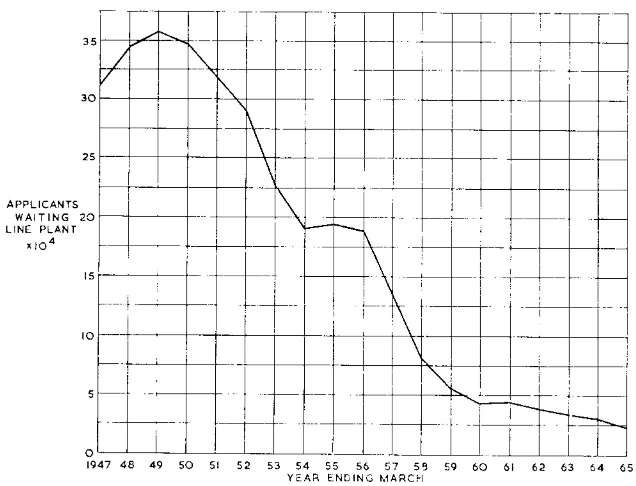

FIGURE **19**—APPLICANTS WAITING LINE PLANT

6. FUTURE FORECAST GROWTH

The present forecast growth of the system is that the number of exchange connexions will reach 17,500,000 in 1981 of which 13,200,000 will be residential and 4,300,000 business. A forecast of the position beyond 1981 must be speculative but when needed for planning purposes a figure of 25,500,000 in the year 2001 has been used. The present forecast of households at 1981 suggests that at this date there will be a residential penetration of about 67 per cent. Telephone growth beyond 1981 is forecast to be at a slightly slower rate than in the preceding years but the residential penetration should increase steadily and be about 74 per cent by 1985. Forecasts of penetration beyond 1981 depends on a forecast of population and the number of households. On the facts which are at

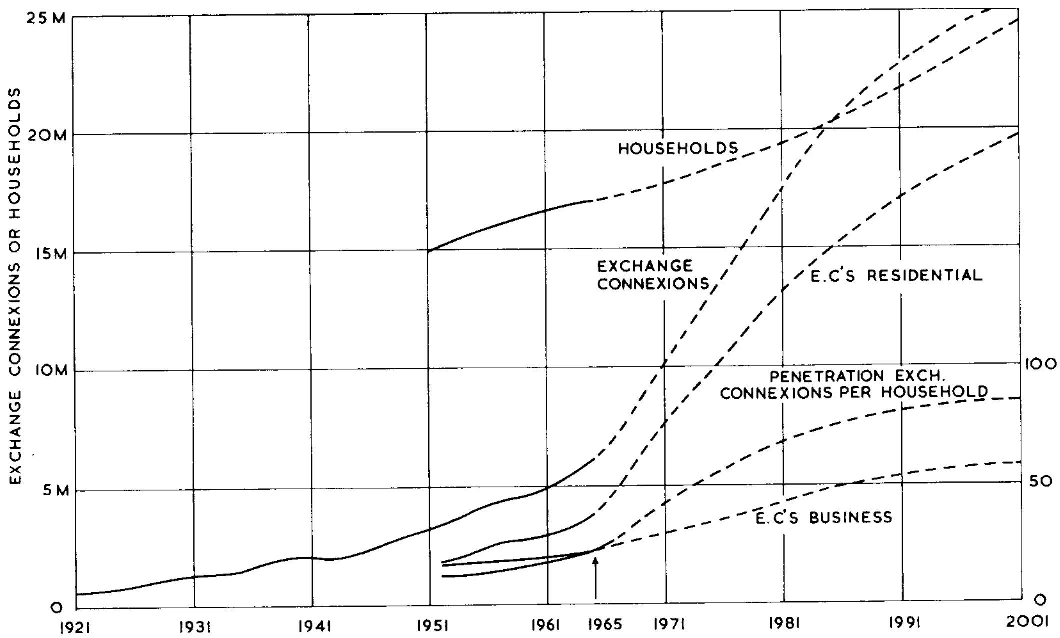

FIGURE **20**—A LONG TERM FORECAST

present available the residential penetration in 2001 could be 85 per cent. These forecasts have been illustrated in Fig. **20.**

A more detailed forecast for the next 20 years has been illustrated in Fig. **21.** The figure shows :

(*a*) exchange connexions.

(*b*) exchange connexions plus pairs required for miscellaneous circuits. Thus this curve indicates the number of pairs required to provide for all exclusive service plus waiting applicants plus miscellaneous circuits. Miscellaneous circuits are assumed to grow at 30,000 pairs per annum—growth over the past 10 years has been 24,000 pairs per annum.

(*c*) pairs in use for shared service. (See paragraph 7.2.1).

(*d*) existing pairs and an estimate, based on recent past experience, of the growth in pairs likely to be achieved in the next seven years.

(*e*) an estimate of the pair requirement to meet the forecast growth curve of exchange connexions plus miscellaneous circuits. The estimate is given in the form of a 'band' with upper and lower limits based on average provisioning periods of 6 and 8 years. The basis of the calculation is given in Appendix I and the estimate is discussed in paragraph 7.1.3.

Is the present forecast reasonable or will history be repeated and the 1981 figure in the event be grossly exceeded? There are good grounds for thinking that the forecast is reasonable and that although the shape of the actual growth curve may differ from that forecast, the 1981 figure is likely to be achieved. At least it is not likely to be exceeded. It is on average over the 16 years a growth rate of 6·8 per cent per annum. All previous forecasts have shown a tendency to 'turn over' some time before the twentieth year. The new forecast does not show this tendency until just before the twentieth year when the residential penetration is forecast to be over 70 per cent (70 residential exchange connexions per 100 households).

The forecast growth curve agrees largely with the forecast made by R. F. Bogaerts[13] who suggests that within a small deviation, each country follows the same general law in the evolution of its line density. Line density is the number of exchange connexions per 100 population. At present the residential penetration in the UK is 25 per cent (25 residential exchange connexions per 100 households) or a line

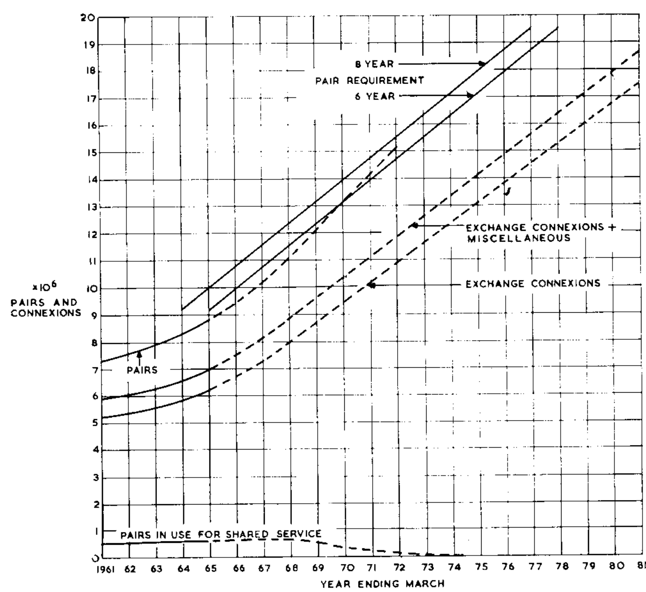

FIGURE **21**—A FORECAST OF PAIRS AND EXCHANGE CONNEXIONS density of about 11 per cent (total exchange connexions per 100 population). The forecast figures for 1981 are 68 per cent and 28 per cent respectively. Sweden and the United States have the highest penetration and line density, and it would appear that the UK is lagging about 20 years behind.

7. THE NEXT 20 YEARS

7.1 The immediate task

The task in the next 20 years is to consolidate the local line network, extend it to meet the rapid expansion in growth of the next four or five years and then to keep pace with the steady growth thereafter. This immediate need can only be met by the provision of individual cable pairs from subscribers premises to the exchange, because no other more economical method is at present available.

Maximum advantage must be taken of new materials and methods of construction and account must be taken of the effect of increased telephone penetration. The following paragraphs deal with the immediate expansion of the network.

7.1.1 *Distribution Section*

With an overall penetration of 74 per cent in 20 years it will be economic in the vast majority of instances where new or additional line plant is required to provide for at least one pair for each household in the distribution section of the network. This is particularly necessary where the distribution cable is laid directly in the ground either to serve a drop wire DP or direct underground leads-in. Overhead DPs must be sited so that every household can be reached with one span of dropwire.

In those instances where the forecast penetration is low it will not be economic to provide one pair per tenancy in underground cable to DPs within one span of every household. The method of distribution in these instances will depend on the actual conditions, but self-supporting aerial cable feeding drop wire DPs can be used effectively. Pair provision should be related to the forecast.

The total number of DPs at March 1965 was 1,060,000 and the average DP had 5.68 exchange connexions. With an increase in telephone penetration the number of exchange connexions per DP will increase. A reasonable assumption is that the number could be 8 by 1981, that is, the average DP capable of serving 11 or 12 houses has 8 working subscribers. On this assumption 2,200,000 DPs would be required by 1981. This represents an increase of 1,140,000 DPs in 16 years or 71,000 per annum. (Assuming 7.5 exchange connexions per DP, increases this figure to 80,000.)

During 1964-65 the growth in the number of DPs was 65,000—an increase of 19 per cent above the 1963-64 figure of 55,000. A similar increase in the DP growth in the current year followed by a 15 per cent increase in each of the two following years should result in the DP growth exceeding 100,000 per annum in 1967/68.

A growth of this order should ensure that the line plant in the distribution section of the network will be sufficient to enable the majority of the exchange connexions envisaged by the forecast to be provided either by single spans of drop wire erected as required or by direct underground leads-in provided in advance.

A growth rate of 100,000 DPs per annum should only be necessary for 4 to 5 years, thereafter 50,000 to 65,000 should be sufficient to cater for future development which will be mainly associated with new building.

7.1.2 *Branch Cable Section*

The need for cabinets and pillars in tandem will be gradually reduced with the increased penetrations now forecast. Pillars connected to cabinets will only be required in a few special instances and the branch cable section of the network will gradually disappear.

7.1.3 *Main Cable Section*

It is in this section of the network where savings in the provision of cable pairs can be achieved. Provision can be directly related to need and provisioning periods reduced to an absolute minimum.

It has been shown previously[14][1] that as the rate of growth increases the economic provisioning period becomes shorter. This phenomenon has always presented a problem to the planning engineer for, as the forecasts of requirements are assembled back from the distribution point towards the MDF, the rate of growth increases and so the economic provisioning period becomes shorter. Fig. **22** shows the relationship between the present value of annual charges and

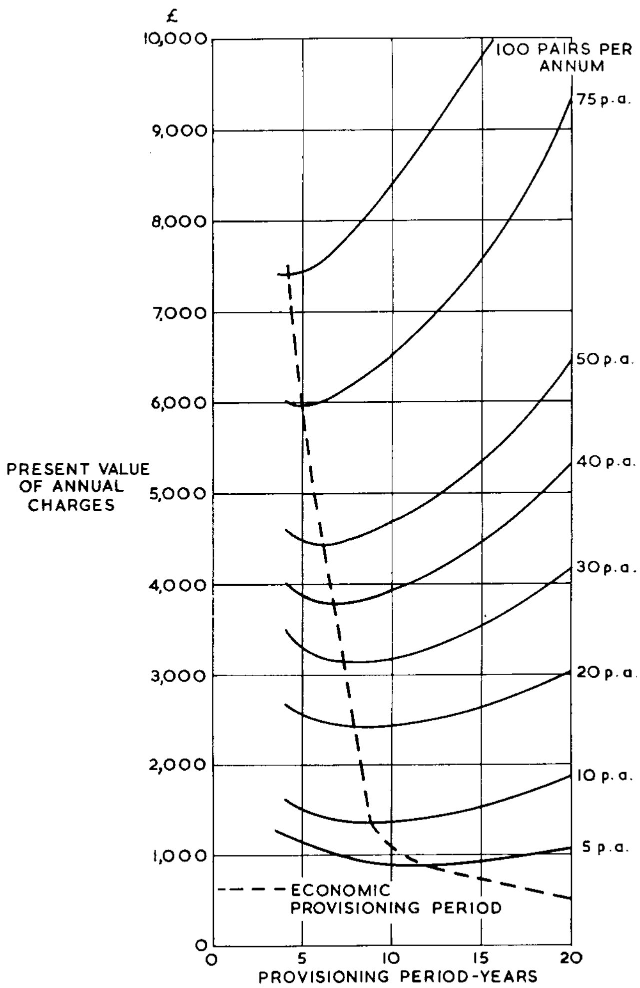

FIGURE 22—ECONOMIC PROVISIONING PERIOD : 4 lb CABLE : LINEAR GROWTH RATE

provisioning periods for a linear growth rate. If the economic provision of cable pairs is made for each section having a different forecast, then a mismatch of cable pair sizes and differing provisioning periods results, leaving a cable network difficult to relieve without rearrangement and a large amount of unusable cable pairs. The introduction of cabinets has enabled the main cables to be planned with optimum economic provisioning periods.

Graphs have been produced to assist planning engineers in choosing the economic relief cable size (Fig. **23** is a typical graph). It is the policy to round down to the next cable size for the spur cable to the cabinet, in order to assist in reconciling the comparatively low growth rates at cabinets with the higher growth rates as other spur cables are joined into the main cable. No adjustment of cable sizes is made purely to obtain the same exhaustion date for each cabinet along the route, since it is recognised that this rarely happens in the event, the aim being to relieve cabinets or pillars as separate units. This lends itself to simplicity of design and execution of the work while at the same time giving a reasonable overall economic layout.

Fig. **21** includes an estimate of the total number of cable pairs likely to be achieved during the next seven years. This estimate is based on the achievement in the immediate past five years and an estimate of the rate at which effort in the provision of local line plant can be accelerated.

The number of pairs added in **1963/64** was **344,000** and in **1964/65** was **483,000**, i.e. an increase of **40** per cent. If it is assumed that an increase of **25** per cent per annum can be achieved in the next few years the provision rate will exceed **1,000,000** pairs per annum in **1968/69** (i.e. more than twice the existing rate). Although this is a high figure it should be appreciated that many of the added pairs will be a straightforward augmentation of existing cable routes to cabinets which can be carried out at low cost (see paragraph 3.7). After **1968/69** a provision rate of **1,000,000** pairs per annum will meet the requirements of the forecast growth curve given in Fig. **21.**

On present trends with the improvement of productivity now being achieved in the provision of plant, the cost per added pair should be reduced from **£32·4** in **1964** to **£24·5** in **1970**, i.e. an average reduction of about **5** per cent per annum.

7.1.4 *Flexibility Points*

A lesson for the future provision of flexibility points was mentioned in paragraph 3.2, that is, that cabinet shells must be provided on a generous basis. Flexibility units should be of sufficient size to cater for the maximum possible requirements within the areas they will ultimately serve. In residential and industrial development areas, they must be installed at the earliest stage to provide a terminating point for subsequent cable provision and thus to avoid later re-arrangements.

With the penetration expected in the future, planning should be on the basis of the provision of large cross connexion cabinets with a capacity of **600-800** circuits. Recent studies show that a network having

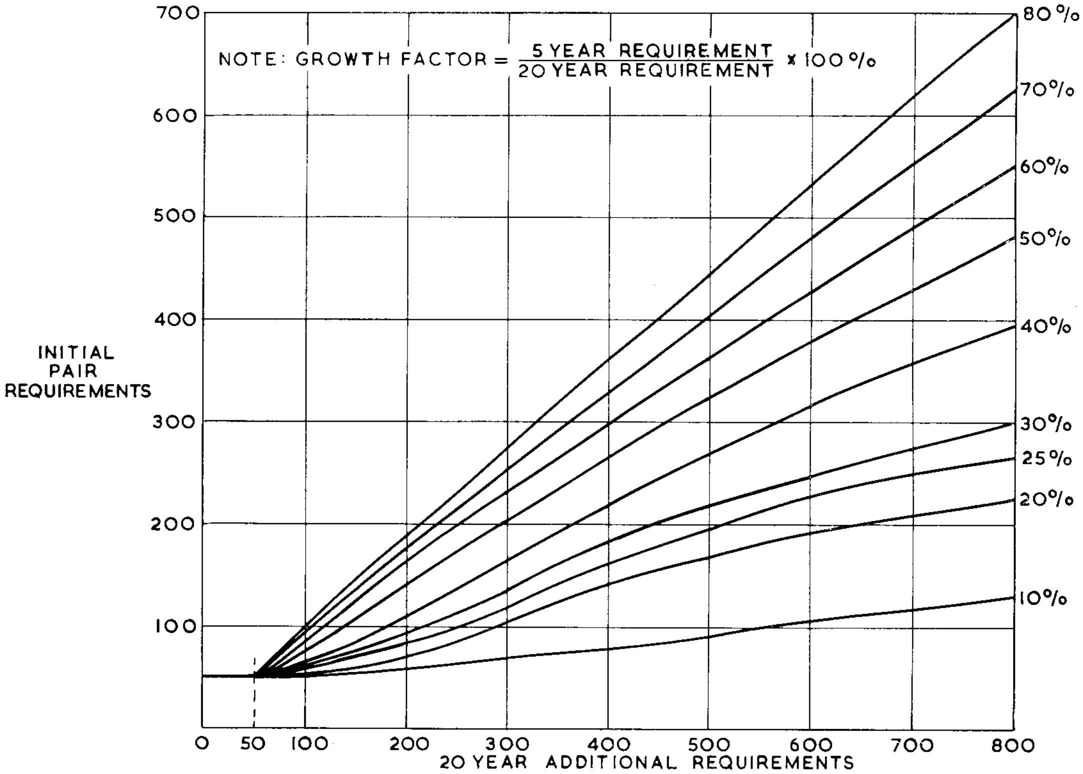

FIGURE **23**—INITIAL PAIR REQUIREMENTS FOR DIFFERENT GROWTH FACTORS : 4lb CABLE single flexibility units of this size is likely to be the most economic in the built-up areas where most of the future growth will occur. For a contemporary high density housing estate, an 800 pair cabinet will serve an area equivalent to a $\frac{1}{4}$ mile square, i.e. provision for 20 cable pair terminations per acre. Enquiries from the Ministry of Housing and Local Government lead to the conclusion that in residential territory where there is any doubt as to the future prospects of building, the provision of cabinet terminating space at the rate of 20 terminations per acre (including open spaces) is a reasonable provision.

One result of increased penetration is that cable pairs are required to remain permanently connected to households because even if the line is ceased it is immediately taken over again by the incoming occupier. In these conditions the provision of full flexibility at cabinets may not be necessary and the present system in which every cable pair is terminated on an assembly could be gradually replaced by cabinets in which E and D side cable pairs are permanently joined together in batches as required. The cabinet therefore becomes an above ground deferred jointing point providing for longer term flexibility. A fully flexible cross connexion arrangement, will still be required between subscriber's premises and the cabinet so that full advantage can be taken of the saving of cable pairs between the exchange and the cabinet. The second flexibility point will provide for full flexibility. A diagram of the system is given in Fig. **24**.

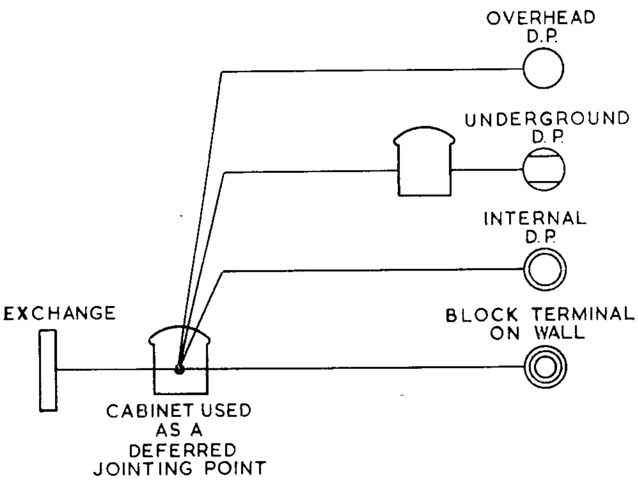

FIGURE **24** – AN ALTERNATIVE SYSTEM OF FLEXIBILITY

An essential feature of this proposal is that once cable pairs are connected in a cabinet *they are never broken down*. Whether or not connexions at the full flexibility point are broken down will depend on the success of the present efforts to sell the telephone to the incoming occupier. For the time being the design of the full flexibility point includes some form of screw connexion but when it is decided not to break down connexions once made to dwellings then a more permanent method of connexion could be used.

7.1.5 *A New Cabinet*

A new type of cabinet suggested by officers of the Midland Region is still in the experimental stage, the first six having been installed in the Solihull exchange area, Birmingham, during 1965 (Fig. **25**). An ingenious method of completely segregating and identifying the cable pairs in the new cabinet has been devised. Each D side pair is passed through a hole in a perspex (or other material) strip so arranged that the number of the pair is immediately identifiable. An E side pair which is required to be jointed to a D side pair is taken through the same hole and after leaving short tails the wires are jointed by means of "Scotchlok" connectors. Unconnected E side pairs are tied together in bunches for future use.

It is intended that jointing work at the new type of cabinet would be done in batches of 25, 50 or 100 pairs according to the circumstances. A necessary feature of the scheme is the use of polythene insulated conductors.

The new cabinet is essentially the old "cable distribution head" with most of the disadvantages overcome, namely it is above ground, polythene insulated cable is used, each wire is identifiable, wires are jointed together and not broken down or re-arranged and access is only allowed and necessary at widely spaced intervals of time. The disadvantages which remain are that unless the rules concerning breaking down and re-arranging connexions are rigidly enforced the cabinet will again become the maintenance hazard similar to the cable distribution head (see paragraph 2.2). Also there is an economic penalty in not allowing connexions to be broken down or re-arranged. Relief cables will be necessary earlier by virtue of the existence of pairs through to DPs and not yet taken into use or ceased.

These disadvantages and the loss of the testing point for fault location are being investigated.

7.1.6 *The Full Flexibility Point*

The present normal terminal block used on a pole or on the outside of a building and the cross connexion frame inside a large building provide for full flexibility at these points. In the case of direct underground distribution a new form of fully flexibility cross connexion joint or pillar is required. Work on the design of two methods is in hand, one, a modern auxiliary joint type of device using flexible screw connexion blocks inside a lead or polythene sleeve and the other, the overground jointing point on fairly extensive trial in the Midland Region.

7.2 Future developments

7.2.1 *Telephone Service*

The search for alternatives to the use of individual cable pairs from each telephone to the exchange has exercised the minds of telecommunication engineers ever since the days of the duplex telegraph which was probably the first attempt to obtain two circuits from one wire.

FIGURE **25**—A NEW CABINET

The first alternative to individual pairs was the Party Line to which any number of telephones could be connected in parallel. The objections were lack of secrecy and the annoyance of code ringing. Party lines are still widely used in countries where subscribers lines are much longer and telephone density per square mile is much less than in the UK.

The Country Satellite Exchange introduced in 1936 is an arrangement enabling a maximum of ten subscribers on a party line to enjoy secrecy and normal ringing. There is only one junction to the parent manual exchange and therefore only one call from the group of subscribers can be made at any one time. Calls between subscribers on the same country satellite exchange are possible but the junction is engaged for this type of call. There are still over 20 of these exchanges in the remoter parts of Scotland.

Subscribers Group Service was introduced in 1933 as a means of giving service to a maximum of eight subscribers over one speaking pair and one control pair to a manual or an automatic exchange. The switching relays were mounted in a box on a pole. The chief disadvantages were that calls between subscribers on the service were not possible and that it was impossible for a second caller to make an emergency call. The service was withdrawn in 1948.

Shared service was introduced in 1942 as a means of meeting demands for telephone service which could not otherwise be met. It has never been popular and there has always been pressure from outside sources not to continue with it. However, as mentioned in Cmnd 2211 "The Inland Telephone Service in an Expanding Economy"—"The first priority will be to give telephones to those who want them even if at the start some have to share. So, in the short term, sharing will continue. But the ultimate aim is to remove compulsory sharing and to give exclusive service to all who want it".

Shared service must therefore be used to meet demands in the immediate future but long term plans must make provision for all exclusive service. The graph of pairs in use for shared service in Fig. **21** is drawn on the assumption that the number will increase slightly in the next few years and then gradually be reduced to zero in about 1975. The estimate of pair requirements in Fig. **21** does not take this into account and is drawn on the assumption that all exchange connexions are exclusive. It is assumed that any short fall between the actual pairs provided and the estimated pair requirement will be met by the use of shared service.

A Line Connector (Concentrator) is similar to group service in that it uses common cable pairs (links) from the MDF to a point in the network where automatic switching equipment (the line connector) is provided. Individual connexions are provided from the line connector to each telephone. Additional switching equipment is necessary at the exchange. The types of line connector which have been used in this country are listed in Appendix 2.

The use of a line connector with only two links to the exchange has led to service difficulties and this type of unit is not popular. The main trouble arises because a call between two subscribers on the same unit engages both links and so prevents the other subscribers from using the telephone or receiving incoming calls.

The provision of automatic switching equipment in a protected box between the subscribers premises and the exchange is costly compared with the provision of additional cable pairs on a planned basis and hence the present line connectors do not generally prove economic for normal development[15]. However, they are very useful as expedients when they can be installed quickly to give service to waiting applicants.

Subscribers Carrier Systems modelled on the same lines as trunk and junction carrier systems are in use in other countries where there are some very long (up to 25 miles) subscribers circuits. These systems are costly and their use could never be justified economically in this country where there are very few lines over 5 miles in length.

Experimental systems have been tried in the UK using conventional modulator, demodulator and filter methods both with thermionic valves and transistors. Up to the present time it has not been possible to produce equipment which can compete in cost with the provision of line plant either as an expedient or as part of planned development.

Time Division Multiplex Systems have received consideration for use in the local line network and ultimately it may be possible to extend an integrated trunk or junction system as far as the cabinet.

It is considered that the most promising of the methods of economising on line plant at the present time is the subscribers carrier system. It should be possible, with the rapid progress now being made in the design and manufacture of electronic equipment, to produce a simple cheap subscribers carrier system within the next few years. A system providing for up to three carrier channels is feasible on the existing network.[16] Such a system could be used either to give service to new households or, what might be more useful, to provide a second service in a household.

Whatever future system evolves, unless some cheap form of radio or other electromagnetic wave system is developed, a pair of wires must be taken from each subscribers premises to a point where some form of concentration is economically justified. Bearing in mind the high cost of the installation of a cable relative to the pair cost and the shortening distance from the subscribers premises to the cabinet, the economic point of concentration will generally be the cabinet.

7.2.2 *Other Services*

Consideration of the future must include the possible use of the local line network for purposes other than telephony and at frequencies above the audio range. The use of carrier frequencies for normal subscribers telephony is mentioned above. There are many possibilities for other uses. In the UK one carrier wired-broadcast system employing double side-band transmission for speech, signalling and tele-control tones is already in use. Two other systems are on trial, one for music distribution and one for telecontrol purposes.[17] On the continent multichannel systems of this kind are in use for program distribution.[18][19]

Other applications which are possible include metering and signalling to or from the telephone on the line concerned, data links, burglar and fire alarm concentration, electricity or gas meter reading. The possible use of the local line network for purposes other than telephony including the possible provision for an "electronic grid" requiring a new local cable network of cables and amplifiers capable of transmitting frequencies up to many megacycles per second is dealt with fully in the paper "Local Networks" by E. W. Anderson[16] to which reference should be made for further information.

8. CONCLUSIONS

An endeavour has been made in this paper to show that the decision made in 1945 to adopt the recommendations of Mr. Harvey Smith's report has proved to have been satisfactory for the development of the telephone service in the UK during the post war years.

The aim of the recommendations has been achieved and a system has been developed which has the advantages of the Ericsson cabinet and the Australian pillar systems. Even in 20 years, however, the system has not been fully applied but much has been achieved and a firm foundation laid for the further expansion of the system to meet the challenge of the forecast rapid expansion in the next 20 years.

A modified system of flexibility has been proposed for use in areas of high penetration and it has been suggested that the application of carrier techniques will play a large part in the development of the network. In the meantime there is much that can be done to reduce the cost and to improve the efficiency of the present methods of planning and provision of plant. It is in this field that maximum advances can be made by the use of modern materials and labour saving devices.

9. ACKNOWLEDGEMENTS

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NATIONAL PAIR REQUIREMENT

The growth of pairs results from the provision of a large number of cables. The size of each cable is dependent upon :

(*a*) the forecast ; and

(*b*) the planning procedure.

The salient features of the planning procedure relative to estimating the national pair requirements are :

(*a*) planning cable fill ;

(*b*) flexibility penetration ; and

(*c*) provisioning period.

Planning Cable Fill

The use of planning cable fill is explained in para. 3.2 of the paper. The values used at present are :

MDF to cabinet 100%

MDF to pillar and cabinet to pillar, 90%

MDF to DP, cabinet to DP and pillar to DP, 50% - 100%

Flexibility Penetration

This is defined as :

$$\frac{\text{pairs MDF to cabinets and pillars}}{\text{pairs MDF to cabinets, pillars and DPs}} \times 100\%$$

Figure **4** shows the growth in flexibility penetration over the years since 1945 rising to 70 per cent in 1965. It is expected that eventually the flexibility penetration will exceed 80 per cent.

Provisioning Period

This is the period of time for which a cable instalment is expected to meet the forecast. For main cables terminating at cabinets or pillars the provisioning period is generally within the range 6 to 8 years. For distribution cables the provisioning period is generally 20 years.

National Pair Requirement

The national pair requirement can be calculated from a knowledge of the average planning cable fill, the average provisioning period and the estimated flexibility penetration.

Average planning cable fill. If the flexibility penetration will be 80 per cent say within 10 years then for every 100 pairs then in the network, 80 may be considered as having been provided at a pcf of 100 per cent, i.e. the forecast was 80. The remaining 20 pairs will have been provided at pcfs of between 50 and 100 per cent, i.e. if we assume an average of 75 per cent the relative forecast was $20 \times \cdot 75 = 15$. Thus for every 100 pairs, the forecast was 95, i.e. an average pcf of 95 per cent.

Average provisioning period. For many years the national pair requirement considered necessary to give satisfactory service was derived by using average provisioning periods of 8 to 10 years. Various factors suggest that future pair requirements should be derived by using shorter provisioning periods of 6 to 8 years. These factors are :

(*a*) The higher growth rate justifies a shorter provisioning period.

(*b*) The increase in the number of areas where telephone penetration is approaching or has reached 100 per cent and hence a smaller spare pair margin is satisfactory.

(*c*) Relief to main cable is at present limited to cabinets with less than four years growth in hand and hence the average spare pair margin at cabinets falls to a lower figure before relief is provided.

(*d*) The existing total pairs (March 1965) approximates to the pair requirement based on a 6-year provisioning period (see Fig. **21**) and although there are difficulties in some parts of the country the number of applicants waiting for line plant is rapidly going down. (The effect of shared service is discussed in para. 7.2.1 of the paper.)

If the forecast growth is reasonably accurate and planning methods are not radically changed then at any time the pairs existing should be relative to the forecast requirements at half the provisioning period ahead. The pair requirement at 1970 can therefore be calculated as follows :

	Millions
Forecast exchange connexions plus miscellaneous at 1973 ...	12·6
Pair requirement for 6-year provisioning period, $\frac{12\cdot6}{0\cdot95}$	= 13·3
Forecast exchange connexions plus miscellaneous at 1974 ...	13·4
Pair requirement for 8-year provisioning period, $\frac{13\cdot4}{0\cdot95}$	= 14·1

TYPES OF LINE CONNECTORS

Type	*Capacity*			*Suitable for Shared Service*	*Subscribers' Unit*		*Power Supply Required*	*Suitable for Subscribers' Private Meter*
	Sub-scribers	*Links*	*Control Pairs*		*How Mounted*	*Type of Equipment*		
No 1	10	2	Nil	No	Pole	Remanent relays	No	No
No 1A	10	2	Nil	No	Pole	Remanent relays	No	Yes
No 2	22	4	Nil	Provision is made for 10 S/S subs. but a maximum of 22 subs. cannot be exceeded	Cabinet No. 1 modified for ventilation & depth. Two can be installed in a Cabinet No. 3	Conventional relays and uni-selectors	Yes — 24V lead acid battery charged over links	Yes
No 4 Mk I	15	3	Nil	Can provide up to a maximum of 30 S/S subscribers	Pole	Ratchet relay switch	No	Yes
No 4 Mk II	15	3	1	No	Pole	Ratchet relay switch	No	Yes
Gfeller	48	9	2	No	Requires special accommodation	Crossbar switch	No — A large capacitor acts as a reservoir	Yes

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