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The Institution of Post Office Electrical Engineers

# WORLD-WIDE TELEPHONE TRANSMISSION

R. H. FRANKLIN, E.R.D., B.Sc. (Eng.), M.I.E.E.

A Paper read before the London Centre of the Institution on 3rd October, 1961, and at other Centres during the Session.

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## CONTENTS

# World-Wide Telephone Transmission

## 1. INTRODUCTION

Although the title of the paper is "World-Wide Telephone Transmission", approximately one half deals exclusively with national networks because these have a great influence on the design of international networks.

## 2. NATIONAL TRANSMISSION PLANS, OLD AND NEW

Wherever a telephone network is set up it soon becomes impossible to provide circuits from every exchange to every other exchange and collecting centres have to be nominated. This leads to the pattern shown in Fig. **1**. A switching plan of this type is suitable for countries with a very low telephone density but, as the number of telephones increases, more exchanges are opened and there is a need for subsidiary collecting centres; the pattern shown in Fig. **2** then arises which is the United Kingdom transmission plan of 1922. There were then 13 fully interconnected zone centres and 77 group centres. For the conditions then prevailing this was a very good plan but more and more exchanges were opened and it became necessary to introduce an additional collecting centre between the group centres and the dependent exchanges. This is shown in Fig. **3** and is the 1933 United Kingdom plan. In this plan the loss introduced between local exchanges was not to be greater than 15 db but this unfortunately was never achieved in practice—for three reasons.

Firstly, advantage was not taken of the facility offered by the sleeve-control switchboards of lining-up circuits from switchboard-jack to switchboard-jack. The plan had assumed that this would be done. Secondly, the zone-zone circuits were planned to have zero loss; they also had to be unconditionally stable, that is, they must not oscillate when the ends are short-circuited or open-circuited. A trunk circuit is a four-terminal network and it has a pair of image impedances. If it is lined up to have zero loss between its image impedances then the circuit will be just stable when the ends are short-circuited or open-circuited. If impedances not equal to the image impedances are used when lining-up to zero loss, the circuit must provide a little extra gain to cancel out the mismatch losses at the ends and then it will oscillate when the ends are short-circuited or open-circuited.

Test gear with an impedance of 600 ohms is used and since there is always some frequency at which the impedance of the circuit is other than 600 ohms non-reactive, zone-zone circuits were never zero loss; they were at best about $1\frac{1}{2}$ db.

The third reason was a question of economics. It frequently happened that the minor-group link was an amplified circuit lined up to 3 db loss. This meant that the maximum allowable loss between minor and dependent exchanges was only 1.5 db, which was reasonable for the open-wire junctions used in rural areas. As traffic increased, underground cables were laid and heavy conductors at high cost had to be used if the plan was to be adhered to. Sometimes it was too costly to follow the plan so that the total loss between dependent and group via a minor exchange was more than 4.5 db.

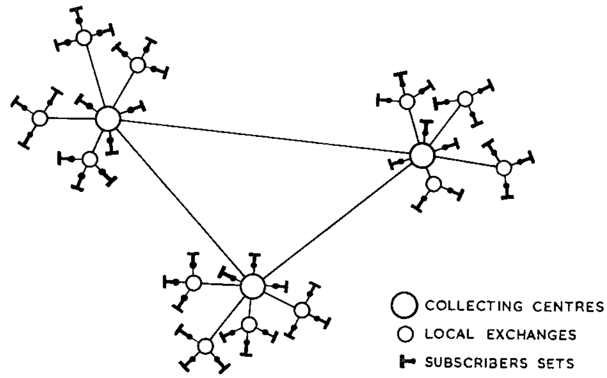
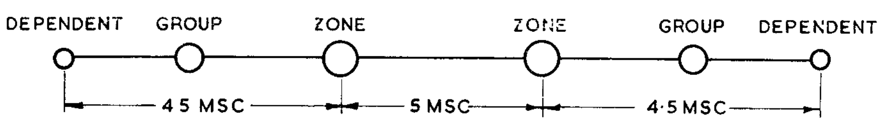
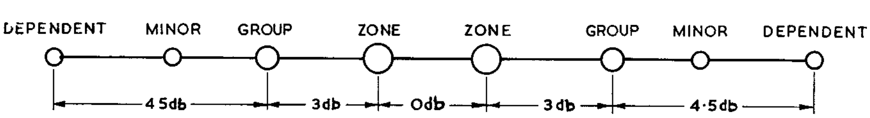



FIG. 1.—USE OF COLLECTING CENTRES TO REDUCE THE NUMBER OF DIRECT CIRCUITS BETWEEN EXCHANGES.



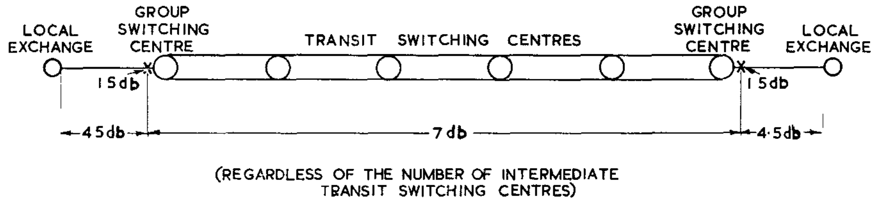

Four Exchanges at 1.5 MSC each = 6 MSC. Lines = 14 MSC. Total Loss = 20 MSC. = 18.4 db.
MSC = Mile of Standard Cable. 1 MSC. = 0.92 db.

FIG. 2.—UNITED KINGDOM TRANSMISSION PLAN—1922.




Six Exchanges at 1.5 db each = 9 db. Lines = 15 db. Total Loss = 24 db.

FIG. 3. UNITED KINGDOM TRANSMISSION PLAN—1933.




Two Exchanges at 1.5 db each = 3 db Lines = 16 db. Total Loss = 19 db.

FIG. 4.—UNITED KINGDOM TRANSMISSION PLAN—1962.

For these three reasons, the overall loss between exchanges can be 27 db which is on the high side for a modern network. There are 26 zone centres and about 250 group centres in this scheme.

The latest United Kingdom transmission plan is shown in Fig. **4**. It is designed to give a lower overall loss between exchanges by switching the circuits together four-wire at the transit switching centres and lining-up the circuits to compensate for the losses introduced by line relay sets and exchange cabling. The maximum nominal transmission loss between exchanges in this plan is 19 db so that it has taken 40 years to get back to within half a "planning db" of the 1922 figure of 18.4 db. During this period however 300 extra group centres have been created.

## 3. THE LOCAL LINE

Before examining the new transmission plan in more detail, it is well to consider the United Kingdom subscriber's line. There are millions of these and they must therefore be as inexpensive as possible. With modern telephone instruments and transmission bridges, the maximum allowable line resistance is 1,000 ohms when using $6\frac{1}{2}$ lb underground cable. Corresponding maximum figures for other cable conductor sizes are shown in Table 1.

TABLE 1

*Transmission Performance of Limiting Local Lines of Uniform Construction*

*50V Stone transmission bridge with 50+50 ohm relay and ballast resistor; direct exchange line; 700-type telephone*

| *Conductor Size lb/mile* | *Limiting Length miles* | *Loop Resistance ohms* | *Microphone Current mA* | *Feeding Factor db* | *Line Loss db* |
|---|---|---|---|---|---|
| $2\frac{1}{2}$ | 2.1 (1.5) | 1450 (1000) | 30 (40) | 1.8 (0.0) | 8.2 (5.8) |
| 4 | 2.8 (2.3) | 1250 (1000) | 34 (40) | 1.0 (0.0) | 9.4 (7.8) |
| $6\frac{1}{2}$ | 3.7 | 1000 | 40 | 0.0 | 10.3 |
| 10 | 4.7 | 830 | 47 | —1.0 | 10.7 |
| 20 | 7.6 | 670 | 55 | —2.0 | 12.1 |

In the table, the feeding factor allows for a microphone feeding current other than 40 mA; the line loss is the line attenuation at 1600 c/s; and the figures in brackets are those imposed by the signalling limit of not more than 1,000 ohms loop resistance.

It is seen from Table 1 that the effective transmission loss of the limiting subscriber's line is of the order of 10 db. The effective loss of a local call is the sum of the two line losses and one feeding factor giving a maximum of about 20 db.

Most subscribers' lines are less than 3 miles long so that $6\frac{1}{2}$ lb conductors are generally the heaviest that need be used. At the present time the signalling limit of 1,000 ohms is generally the limiting factor so that there is no advantage in allowing greater transmission losses in subscribers' lines. But this may not be true if there is a change in the local line signalling system and this may happen with electronic exchanges. If there were financial advantages in allowing a greater loss in subscribers' lines, this would have to be done and the losses of the junctions and trunks reduced accordingly.

Having established, in a somewhat arbitrary way, the maximum subscriber's line, it is necessary to decide how much loss can be permitted in the chain of trunk and junction circuits. Fig. **5** shows the percentage of subscribers that will be satisfied with the loudness of a call as a function of the transmission loss between their exchanges. Two curves are shown. One

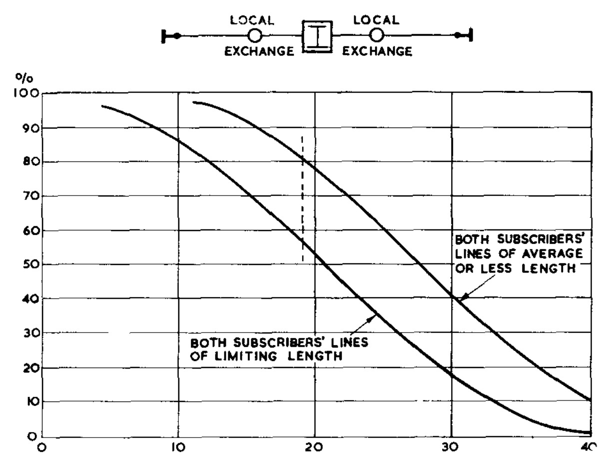



FIG. 5.—PERCENTAGE OF SATISFIED SUBSCRIBERS AS A FUNCTION OF THE LOSS BETWEEN LOCAL EXCHANGES.

applies when both the subscribers have limiting lines and the other when they are both of average or less than average length. The regulator in the modern 700-type telephone instrument is the reason why the shorter lines can be classed as average lines.

The curves, Fig. **5,** are not a great deal of help in deciding what is the best value of the loss between exchanges. They simply demonstrate that the lower losses are more acceptable than higher ones, and provide no clearly defined planning limit. With 20 db loss between local exchanges about 50 per cent of the subscribers with long lines will be satisfied with the most adverse trunk call, and about 75 per cent of the subscribers with average lines.

## 4. THE STABILITY PROBLEM

Consider the connexion shown at the top of Fig. **6** in which two subscribers' lines are switched directly to the ends of a four-wire amplified circuit. Because there is a switch point between the hybrid and the subscriber's line, the balance impedance must be a compromise catering for the variety of circuits that can be connected to the four-wire circuit. In the United Kingdom network the balance impedance is 600 ohms non-reactive, which is as good an average value as any.

The graph of Fig. **6** shows the average value of balance return loss presented by direct exchange lines versus 600 ohms, non-reactive ; 99 per cent of the subscribers' lines exhibit balance return losses that fall within the hatched area. As can be seen the balance return losses at some frequencies can be very low indeed, e.g. 1 db. This means that the four-wire circuit with a pair of such subscribers' lines connected to it could have a gain of 1 db before the connexion became unstable or, putting it another way, if the four-wire circuit had zero loss the connexion would have a stability margin of only 1 db. In practice about 3 db stability margin is needed if 'near-singing distortion' is to be avoided. This means that the four-wire portion of the connexion must not have a loss less than about 2 db. It will be seen later that the four-wire circuit nominal loss must be considerably more.

## 5. ATTENUATION-FREQUENCY DISTORTION

Subscribers' instruments, subscribers' lines, transmission bridges and audio junctions, both loaded and unloaded, all introduce attenuation-frequency distortion. However these occur only twice in a connexion, once at each end, and have to be tolerated because of the need to keep down the cost of local plant.

Turning now to carrier circuits, these might be described as slices cut out of a wide frequency band by somewhat blunt filters. They all exhibit a loss rising at the edges of the transmitted band and there is a minimum near the middle at about 2,000 c/s. Fig. **7** shows the average response of a large number of inland carrier circuits. The loss at 2,000 c/s is about 0.5 db less than the loss at the line-up frequency of 800 c/s, so the first conclusion is that for stability reasons the nominal loss at 800 c/s must be increased by at least this amount. The next point is the large losses at the ends of the bands. An inland call will often include three of these circuits, e.g. Brighton-London-Leeds-York.

An international connexion could have as many as, say, six carrier circuits and it is quite obvious that the response of some of these have to be improved. The dotted line in Fig. **7** would be suitable for an international circuit.

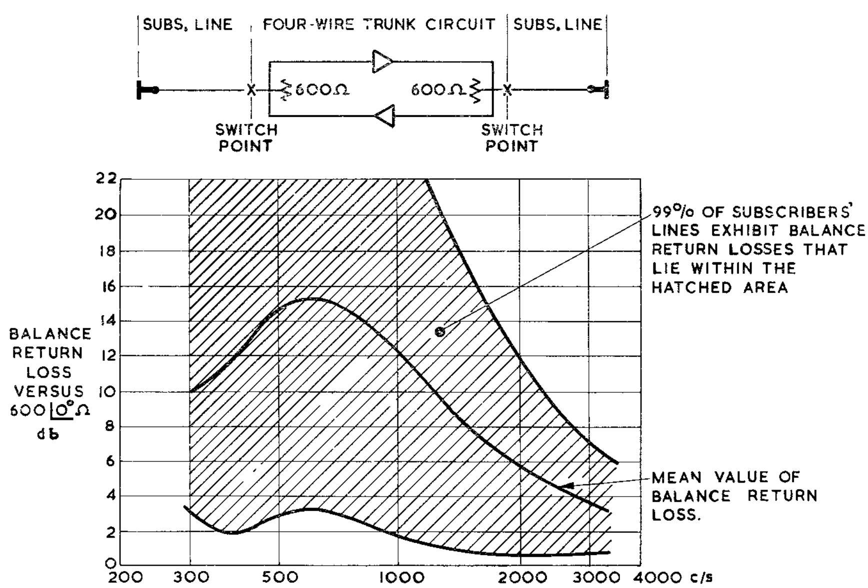



FIG. 6.—BALANCE RETURN LOSS OF SUBSCRIBERS' LINES AND INSTRUMENTS IN THE SPEAKING CONDITION.

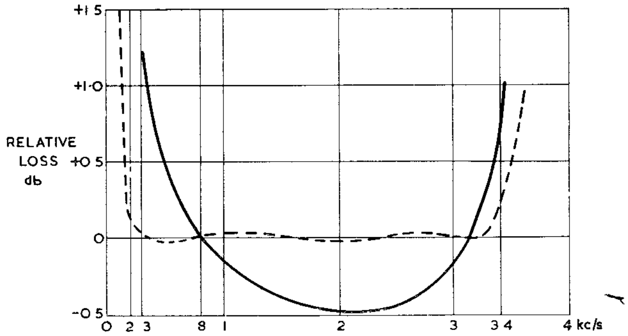



Fig. 7.—Mean Loss of an Inland Carrier Circuit relative to the Loss at 800 c/s.

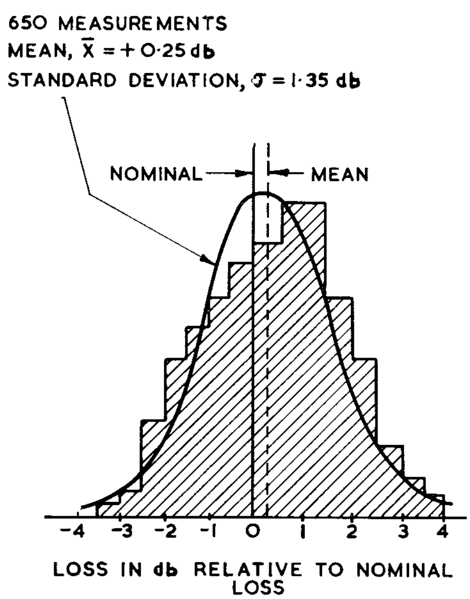
## 6. VARIATION OF LOSS WITH TIME

A most important factor that must be considered when formulating a transmission plan is that the transmission loss of a carrier circuit does not remain constant over long periods. The principal causes of this phenomenon are changes in temperature and power supplies and component ageing, valves in particular. Others would add "our present maintenance technique" to this list of causes. This will be mentioned again later.

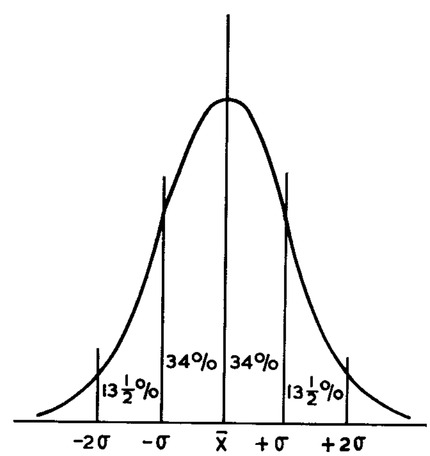
The gain of the h.f. path of a modern coaxial system is affected by the temperature of the cable and power supplies to the line amplifiers. These variations are substantially reduced by using pilot signals at line frequencies continuously to control the gain-frequency response of the complete h.f. path to such a good effect that the gain at any frequency in the useful band of a modern 12 Mc/s coaxial system 500 miles long is held to within ±0.5 db of nominal. On older systems still in service, the gain-frequency response is controlled manually and channels, particularly in the upper end of the line spectrum, suffer sudden jumps in gain. At one time these were as much as 3 db, but they have now been reduced by refining the control. The group and supergroup translating equipment add their contribution to the variations. However, each 12-channel group is, or will be, equipped with 'group automatic gain control (a.g.c.)' which reduces variations at the group pilot frequency by about 90 per cent. It cannot correct for slope over the 48 Kc/s group band, but modern line systems are quite satisfactory in this respect.

Channel translating equipment is outside the group a.g.c. path and introduces variations in gain that are much larger than those introduced by a modern well-maintained group link. The principal cause of variation in modern channel equipments is again temperature changes, this time on channel filters, modulators and demodulators. To eliminate these variations would mean fitting channel a.g.c.; this is not done because of cost and because it would contribute too much to the load on the h.f. link. An alternative would be to arrange for a routiner to test the circuits at fairly frequent intervals and to control an adjustable pad to bring the circuit to within, say, 0.2 db of its nominal value.

Fig. **8(a)** is a pillargraph showing the distribution of loss of a large number of inland carrier circuits not fitted with group a.g.c. The smooth curve is the normal distribution that would be used to describe compactly the actual distribution. The two parameters of this normal distribution are the mean value, which is not necessarily the same as the nominal loss, and the standard deviation about the mean value. In the example, the mean value is +0.25 db and the standard deviation is 1.35 db. The significance of the standard deviation is illustrated in Fig. **8(b)**. It will be seen




(*a*) Normal Curve with the same Mean and Standard Deviation as the Measured Distribution.




(*b*) Curve showing how the Standard Deviation defines the Percentage Distribution when the Distribution is normal.

Fig. 8.—Distribution of Loss of Inland Carrier Circuits not fitted with Group Automatic Gain Control.

that 68 per cent of the samples lie within plus and minus one standard deviation either side of the mean. If the range is extended by another standard deviation on each side 95 per cent of the samples are embraced.

New York-London circuits are routed in groups fitted with group a.g.c. and are carefully maintained. The mean deviation from the nominal loss is zero and the standard deviation from the mean is only 0.7 db. This is a substantial and very worthwhile reduction in the standard deviation and if it can be achieved on long complicated circuits it should be possible to do it on the relatively short and simple inland circuits. This is essentially a maintenance problem. There is evidence to show that the present method of routine testing is not the most efficient way of maintaining the losses of a trunk network and a sizeable proportion of the standard deviation has been directly attributed to needless maintenance readjustment.

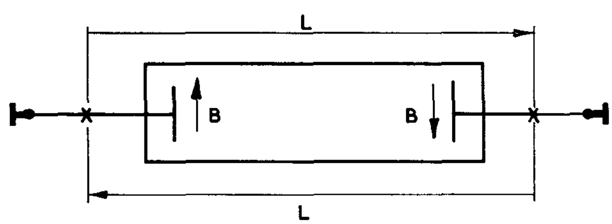
There appear to be two alternative ways of attacking this problem, either to use an automatic routiner frequently to readjust the gain of the circuit, or to institute quality control of circuits. Briefly, quality control is a method in which relatively small samples of the circuits are examined fairly closely and the statistics of the samples can be a guide to the behaviour of the circuits from which the samples were taken. This method is claimed to save a lot of maintenance effort, which is alleged to be misdirected at present, and also to reduce the standard deviation by eliminating needless readjustments.

The pros and cons of the two methods—automatic routiner and quality control—have yet to be determined. It may be that automatic routiners have merit for circuits between large centres and quality control for circuits between smaller centres.

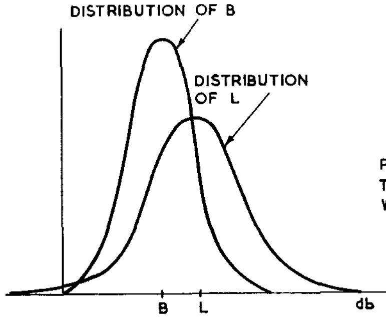
## 7. NOMINAL LOSS OF A CHAIN OF CIRCUITS

Earlier, the minimum loss of a four-wire circuit was discussed briefly and a stability margin of at least 3 db was suggested to avoid near-singing distortion. The stability margin is equal to half the loss round the four-wire loop so that in a symmetrical circuit the stability margin is the sum of the loss of the circuit and either of the two equal balance return losses. This is illustrated in Fig. **9(a)**.

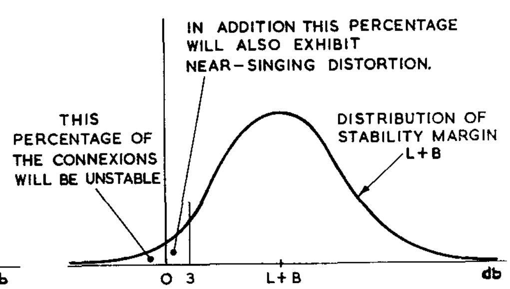
Both the circuit loss and the return loss are in reality distributions of losses about mean values and they must be added statistically. This is demonstrated in Fig. **9(b)** and **(c)**. The curves are not drawn accurately to scale but they do show that the distribution of stability margin, which is the sum of the two distributions, has a worse dispersion than either of them. A portion of the combined distribution is negative which means that a percentage of the total number of connexions will "sing." A somewhat greater percentage will have a stability margin less than the recommended value of 3 db. The problem is that given B, what should be the value of L so that only a very small percentage of connexions exhibit near-singing distortion. The difficulty of this otherwise simple problem is the meaning of 'very small percentage'; 1 in 1,000 might be regarded as being reasonable. The value of L needed depends on how many circuits are connected together to make up the four-wire portion of the connexion. Fig. **10** shows the shape of the curve and, as expected, this shows that the more circuits in tandem the greater the overall loss must be if the stability margin is to be maintained.




(*a*) The One-way Transmission Loss is L db. The Balance Return Loss at each end is B db. The Stability Margin for this Symmetrical Circuit is given by (L + B) db.




(*b*) Individual Distributions.




(*c*) Combined Distribution.

FIG. 9.—STABILITY MARGIN.

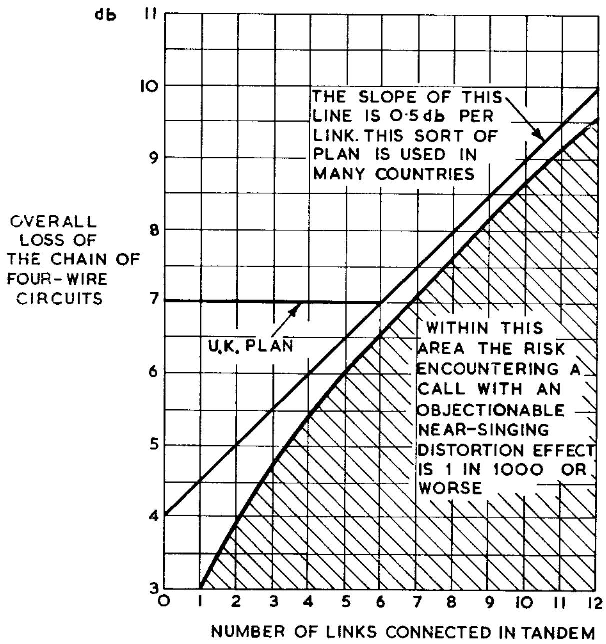


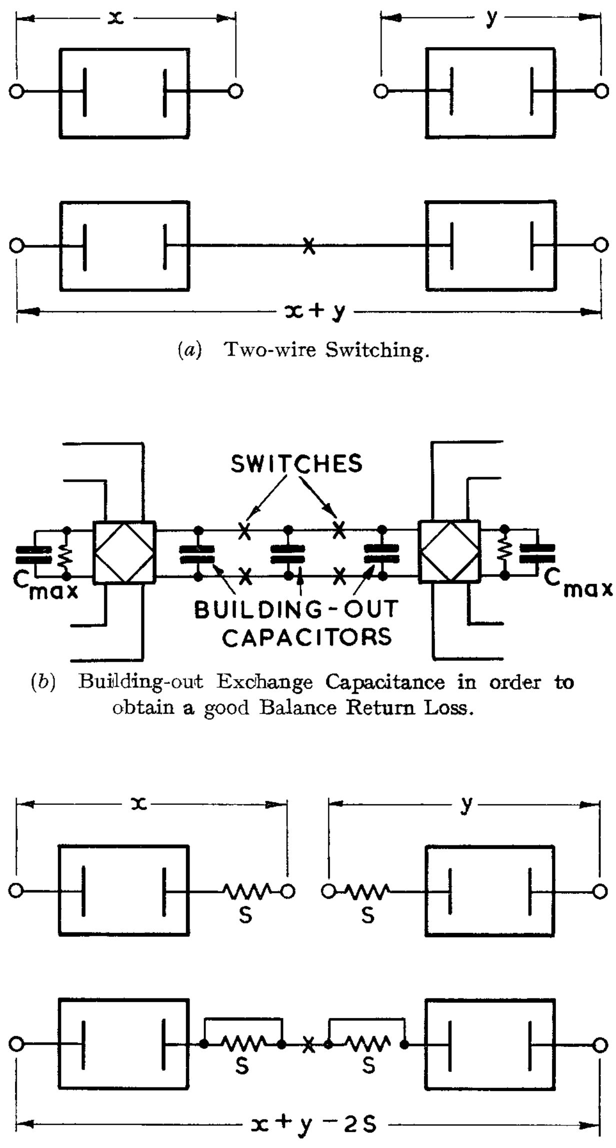

FIG. 10.—TWO TRANSMISSION PLANS.

The straight lines on the graph illustrate two transmission plans. The horizontal one is the new United Kingdom national transmission plan which is basically two $3\frac{1}{2}$ db hybrids with up to five or six zero-loss, four-wire switched circuits between them. That is, the loss is 7 db for any number of links from one to six. The sloping line is another transmission plan used by many countries notably the United States and Canada. In this plan the loss increases as the number of circuits connected in tandem increases.

## 8. INTERCONNECTING FOUR-WIRE CIRCUITS

The least expensive method of connecting two four-wire circuits together in an exchange is ordinary two-wire switching (see Fig. **11(a)**). Each circuit is equipped with a hybrid and a 600-ohm balance resistor before being connected to the switching equipment. The method is simple but has two disadvantages. First, coupling is introduced between the 'go' and 'return' channels of the complete connexion because the balance resistor cannot match accurately the capacitance of the exchange wiring. The amount of exchange wiring depends on the precise route taken through the exchange and the difficulty can be partially overcome by shunting the balance resistor with a capacitor that matches the capacitance of the longest path through the exchange and then building-out all the other paths, if possible, to equal the maximum (see Fig. **11(b)**).

The second disadvantage of this simple two-wire switching system is that the loss of the tandem connexion can never be less than the sum of the losses of the individual circuits, for example, two 3 db circuits will give 6 db. The system known as 'two-wire pad' switching is designed to overcome this difficulty (see Fig. **11(c)**). Each circuit is equipped with a pad at the two-wire terminals of the hybrid and the pads are switched out when the two circuits are connected. The transmission plan fixes the value of the pad. Thus for the United Kingdom type of plan the circuits would be lined-up to have an individual loss of 7 db and $3\frac{1}{2}$ db pads would be switched out so that the overall loss would still be 7 db. For the other type of plan, which increases the loss at the rate of, typically, $\frac{1}{2}$ db per circuit, the circuits would be lined-up to, perhaps, $4\frac{1}{2}$ db and the switchable pads would be 2 db. This system of switching is very flexible, but it is still necessary to build-out and balance the exchange cabling, which creates difficulties in large installations, especially when extensions to the installations are provided.




(a) Two-wire Switching.

(b) Building-out Exchange Capacitance in order to obtain a good Balance Return Loss.

(c) Two-wire Pad Switching.

FIG. 11.—TWO-WIRE AND TWO-WIRE PAD SWITCHING.

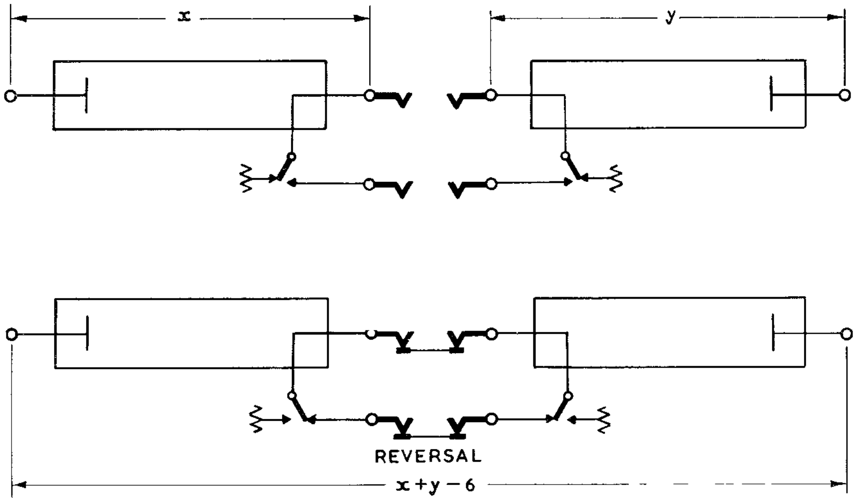
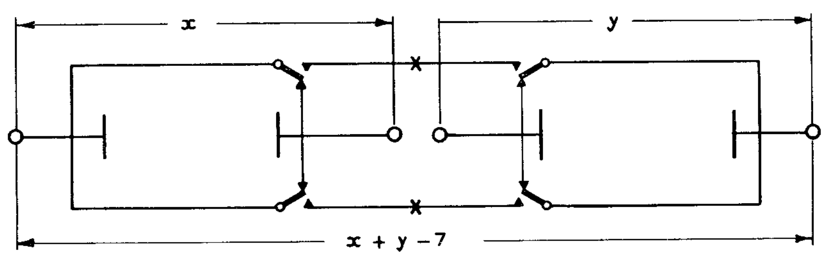


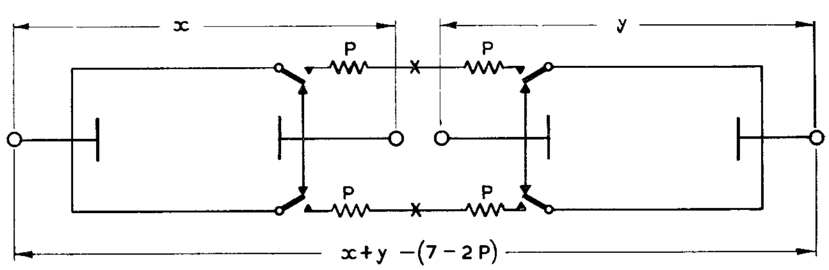

FIG. 12.—TAIL-EATING HYBRID SWITCHING.

Fig. **12** shows another method of switching. In this tail-eating method, the balance connexions, as well as the line connexions, are joined together at the switchboard. This gives a gain of 6 db so that two 6 db circuits joined together by this method will still have an overall loss of 6 db. Tail-eating is only used for circuits operated manually and, for this purpose, it has the obvious advantage of being very simple. Its main disadvantage is that the switching gain is fixed at 6 db. Fig. **13(a)** shows the four-wire switching method adopted by the United Kingdom. This is very simple in principle but requires more bank contacts on the exchange switches. The other feature is that the switching gain is fixed at 7 db; thus two circuits each with a loss of 7 db when fitted with hybrids for a local call will have a combined loss of 7 db when the hybrids at the interconnexion point are removed. If a switching gain other than 7 db is needed then pads have to be fitted and Fig. **13(b)** shows a typical arrangement.

All of these methods are in use in various countries and it is not an easy problem to work out all the possible interconnexion arrangements for international calls.




(*a*) Four-wire Switching—United Kingdom Method.




(*b*) Four-wire Pad Switching.

FIG. 13.—FOUR-WIRE SWITCHING

## 9. THE WORLD-WIDE NETWORK

Earlier, the need for collecting centres was discussed and, in a country the size of the United Kingdom, it is reasonable to have three circuits between the international exchange, which is at London, and a remote local exchange. Larger countries will need four or even five circuits. In an international call from the United Kingdom to France, for example, there will be as many as seven circuits, three in United Kingdom, one international circuit, and three in France. In an extreme case there could be 15 circuits in a call from Punta Arenas in the southernmost tip of South America to an exchange in Java (see Fig. **14**). The total length of the connexion may be 25,000 km (about 16,000 miles) or even more if calls are taken to Asia via Australia as seems likely during the next few years.

To engineer the network so that it is suitable for calls of this type is a formidable task. Often subscribers say that a call from London to New York was better than a call across London. The same comment cannot be expected on calls such as that shown in Fig. **14**.

In general, to make such a call possible, attention must be confined to the international and intercontinental circuits; additional expenditure on subscribers' lines and local junctions cannot be contemplated as there are so many of them.

### 9.1. Attenuation-Frequency Distortion

Carrier terminals used must have low attenuation-frequency distortion. These must be used on all of the international circuits and possibly also on the first inland circuit from the international exchange, for example London-Glasgow. Transit exchanges must not introduce appreciable distortion.

### 9.2. Phase Distortion

Excessive phase distortion may result from the sharp cut-off of the filters in the improved carrier terminals. Phase equalizers may have to be fitted on all intercontinental circuits to eliminate this trouble.

### 9.3. Variability of Loss

Everything reasonably possible must be done to hold the losses of the circuits as close as possible to their nominal values. Fortunately, most of the longer circuits will be on submarine cables which are inherently very stable, and on microwave radio links which can be regulated so as to give very stable circuits. With a.g.c. applied to all groups the overall group stability should be satisfactory. The transmission equipment outside the path regulated by the group a.g.c., that is the carrier terminals, must have stable characteristics and, to give satisfactory performance, power and carrier supplies must be stabilised. At international terminal repeater stations it may also be necessary to control the temperature of the apparatus rooms to within 5°F of a nominal value.

On switched calls the variability of loss through the transit exchanges must also be considered. These exchanges inevitably have a loss of one or two dbs, but this can be looked after by reducing the nominal loss of the circuits by an appropriate amount. But it is important that the loss through the exchange should not vary with time or with the routing through the exchange—a reasonable limit for variations due to these two causes might be 0.2 db.

## 10. NOISE

The next problem to be considered is 'noise'. This is a very complicated subject because noise varies from channel to channel depending on their position in the line frequency spectrum, and, on radio relay links there is, in addition, a wide variation with time. All this adds up to the fact that on a long connexion, made up of several different circuits each routed on a mixture of cable and radio links, the noise level at the terminal is almost unpredictable. Taking as a criterion the mean noise power in any hour, at a point of zero relative transmission level, inland plant will contribute about 3 pW/km and long-distance submarine cable systems 1 pW/km when measured with a suitable weighting network which takes account of the fact that noise in the middle of the audio spectrum is more important than high or low frequency noise. Thus a 25,000 km connexion routed half on submarine cable and half on inland plant may have an hourly-mean noise power of about 50,000 pW. This corresponds to a noise level of 43 db below 1 mW or 26 db below a mean speech power level of —17 dbmO.

This signal-to-noise ratio is barely acceptable and it will be necessary to fit compandors to the worst of the long-distance circuits.

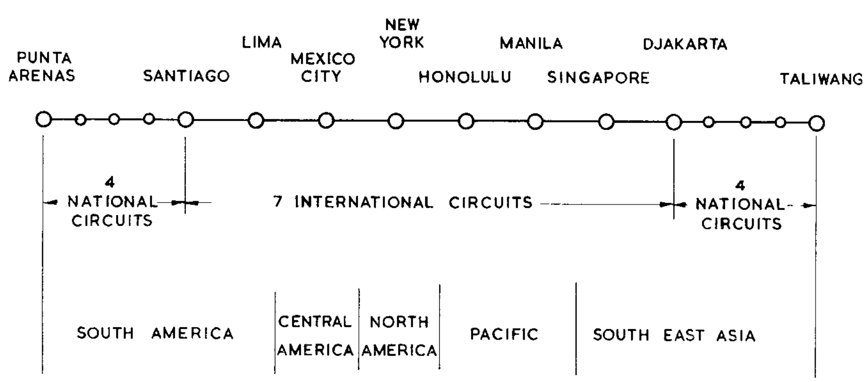



Fig. 14.—A World-wide Connexion.

A compandor is a device designed to reduce the apparent noise on a telephone circuit by suppressing the level of the noise during silent periods. It does this by compressing the volume range at the sending end and expanding it at the receiving end.

It will be seen from Fig. **15**, which is based on an ideal compandor, that an input signal at zero relative level passes through the compressor and the expander with the level unchanged. A mean speech power level of —17 dbmO is transmitted to line at —8.5 dbmO and expanded at the receiving end to its original value. In the absence of speech the expander depresses the noise level by 43 db. When the relatively high-level speech syllables are present the noise is not suppressed, but it is however masked by the speech and is barely noticeable.

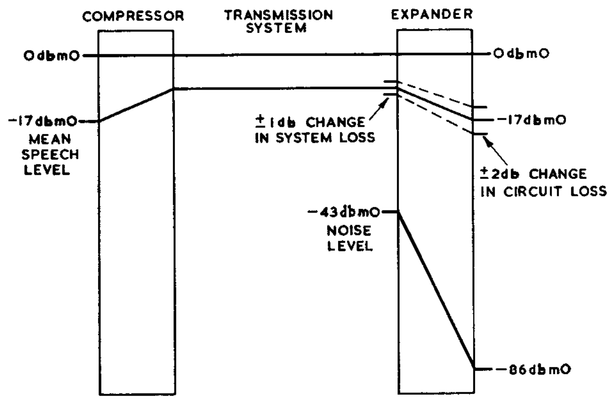



FIG. **15**.—LEVELS ON A COMPANDORED TRANSMISSION SYSTEM. IDEAL 2:1 COMPRESSION RATIO. APPARENT NOISE ADVANTAGE **43** DB.

For the noise level of —43 dbmO the ideal device has effected an apparent noise advantage of 43 db; however the dynamic range of a practical compandor is restricted and the apparent noise advantage is less. This is illustrated in Fig. **16** in which the dynamic range is restricted to —60 dbmO and the apparent noise advantage is reduced to 30 db, which is still very good—even too good. Subscribers have no confidence

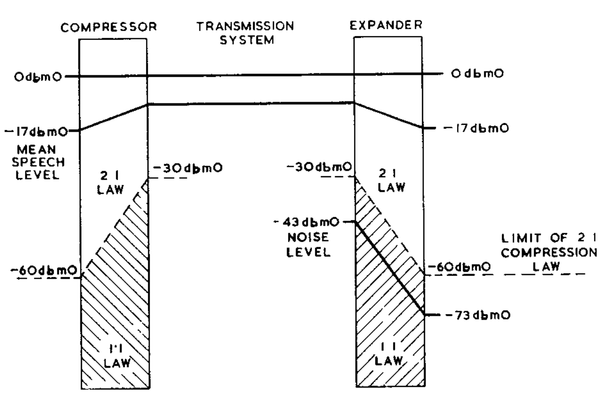



FIG. **16**.—EFFECT OF RESTRICTING THE DYNAMIC RANGE OF THE COMPANDOR. APPARENT NOISE ADVANTAGE **30** DB.

in the perfectly quiet line, a little noise is necessary to assure them that they are still through. Compandors have one serious defect—they increase the effect of variations of circuit loss. If the compandor has a 2 : 1 law the circuit variations are effectively doubled. In many cases the apparent noise improvement given by a 2 : 1 compandor is unnecessarily great and it would be an advantage if a law other than 2 : 1 could be used. For example, a $1\frac{1}{2}$ : 1 law would give an apparent noise improvement of 21.5 db, with the levels assumed above, and increase the variations only $1\frac{1}{2}$ times. An alternative to changing the compandor law which change would probably raise difficulties of international agreement, is to deliberately restrict the dynamic range of the 2 : 1 compandor. However, the variability at high levels within the range is still effectively doubled, so that it is no help in solving the stability problem. When all or many channels of an a.m. carrier system are fitted with compandors the loading of the system is increased. To compensate for this, the signal levels sent to line may be depressed by 3.5 db. This will increase the effect of line noise by the same amount and reduce the apparent advantage, but there is still plenty of improvement left.

## 11. THE ECHO PROBLEM

On a long distance call speech energy reflected from the mismatch presented by the subscriber's line at the far end of the circuit is returned to the talker where, because of the delay time, it appears as an echo. The magnitude of the echo depends on the line loss from the talker to the point of reflexion and back plus the 'return loss' at the point of reflexion. This echo return loss is the average over the whole audio band, and not the worst value within the band, and for a long subscriber's line, is about 5 db. Thus with a zero-loss subscriber's line at London joined to a 7 db circuit to Glasgow and then to a long subscriber's line, the echo attenuation would be 7+5+7 db=19 db. It must however not be overlooked that 7 db is the nominal loss of the circuit and is likely to have a loss differing from this value.

The annoyance effect of echos depends not only on the level of the echo but also on the delay, i.e. the transmission time to the speaking subscriber and back.

To make conditions even more complicated for the system designer, there is considerable variation in subscribers' reaction to echo. In addition there are the variations in line loss and in the balance return loss presented by the subscribers' lines.

Fig. **17** shows results of B.P.O. tests to evaluate subscribers' tolerance to echo. From the curve it will be seen that if in the United Kingdom inland network the one way transmission time can be kept down to 15 mS and the minimum (nominal) loss of the long distance circuit at 7 db, there should be no real echo problem on inland calls. Perhaps 10 per cent of callers from Scilly to Shetland will be in trouble. If necessary remedial action could be taken, for example, by fitting a 700-type telephone with its regulator to reduce the sending level from a short subscriber's line.

Long circuits such as London-New York have a transmission time of about 34 mS and for any reasonable line loss the echo is clearly intolerable. It is then

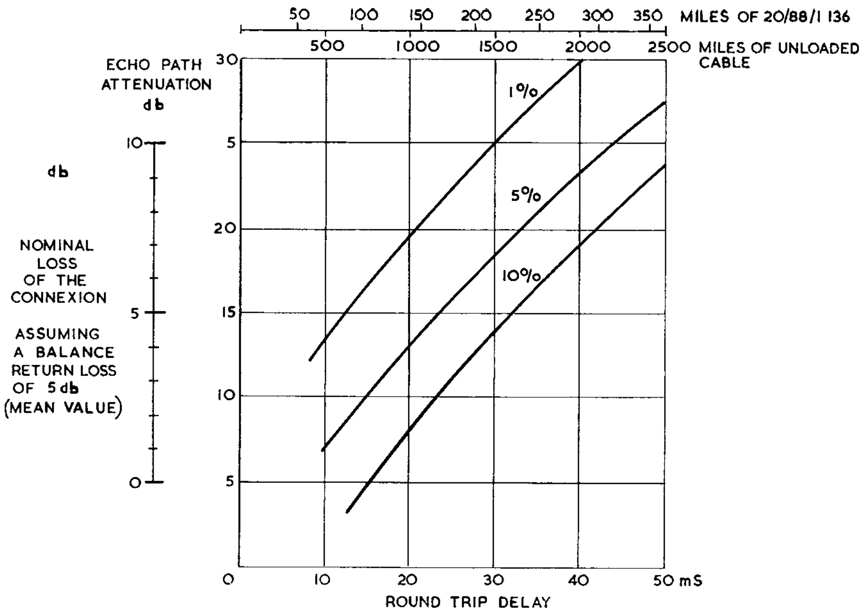
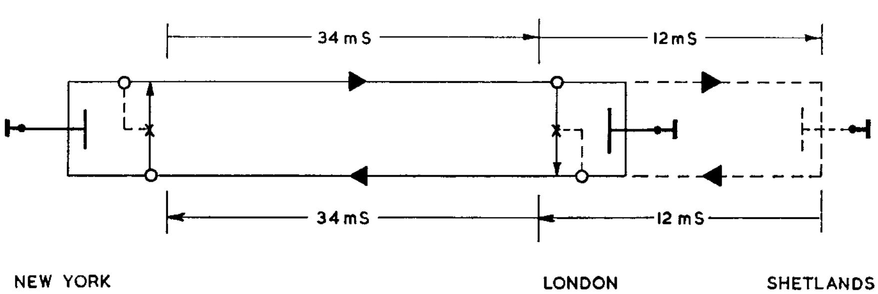



Fig. 17.—Round Trip Delay, Echo-Path Attenuation and Percentage of Objectionable Calls.

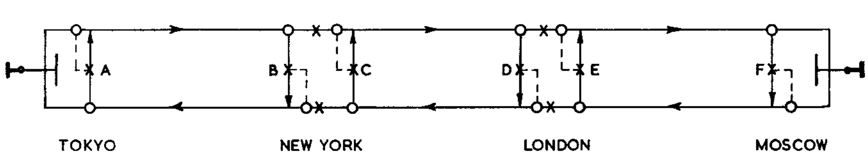
essential to fit an echo-suppressor. The preferred type is the far-end-operated, differential, half echo-suppressor (Fig. **18(a)** ). A speech burst from New York travels to London where it operates the half echo-suppressor which in turn introduces a substantial loss in the return circuit and prevents the echo returning to the New York talker. Similarly when London is talking the half echo-suppressor in New York is operated. These echo-suppressors have a hangover time of up to about 70 mS so that if the call is extended to Shetland, speech, having taken 24 mS to travel to Shetland and back, will find the return path still blocked.

The dotted devices in Fig. **18** are also half echo-suppressors but they do not block the other path ; their function is to fight with the genuine half echo-suppressor for control. One reason for this differential action is to prevent the suppressors locking up on noise which could originate outside the long-distance circuit. These echo-suppressors give excellent results if properly maintained, but they do not entirely solve echo problems.

The first and not very serious difficulty is that an echo-suppressor must not be made too sensitive or it will operate to low-level noise. Therefore, weak speech will not operate it and low-level echo will get through.




(*a*) Single Circuit.




(*b*) Multiplicity of Circuits.

Fig. 18.—Circuits fitted with Echo-Suppressors.

Fortunately, even on the very longest terrestrial connexions, the residual echo is acceptable provided the nominal loss of the connexion is about 7 db or more. Countries using the alternative C.C.I.T.T. switching plan, which allows the loss of a single circuit connexion to be $4\frac{1}{2}$ db, may find the residual echo embarrassing.

The next problem concerns a multiplicity of echo-suppressors in a connexion. If three long circuits each fitted with echo-suppressors are joined together, for example, Tokyo-New York-London-Moscow, Fig. **18(b),** occasionally the Tokyo and Moscow subscribers will be talking at the same time. This will cause the echo-suppressor B at New York and E at London to be operated at the same time and the 'go' and 'return' circuits will be cut simultaneously and both subscribers lose transmission. In practice the differential devices associated with B and E will fight the echo-suppressors and some speech will get through—each subscriber will at least know that the other is trying to talk.

To overcome this difficulty, the switching equipment will be so arranged that when two half echo-suppressors come together, both will be disabled. A possible alternative, which would reduce very much the number of echo-suppressors needed, would be to design the switching equipment to insert echo-suppressors only on calls that need them. This however may involve excessive complication in the switching equipment as the control gear would have to know (*a*) where the call has come from, (*b*) where it is going and the routing, and (*c*) the last point on the routing at which echo-suppressors are available. Of these the starting point of the call is possibly the most difficult to determine from an intermediate point.

## 12. TRANSMISSION TIME

It will always take an appreciable time for speech to travel half-way round the world because the maximum velocity is the speed of light, 186,000 miles per second. In practice, the velocity on h.f. or unloaded plant is about 100 miles per millisec and on loaded cable pairs 14 miles per millisec which adds up to a total of as much as $\frac{1}{2}$ second on a call from London to Malaya via Australia. If the connexion were four-wire throughout and with four-wire telephones, so that there is no echo, it is not impossible to carry on a conversation with a delay of this order of magnitude. As two-wire telephones are used echo-suppressors must be fitted to eliminate the echo. If the two subscribers talk within half a second of one another, the two half-echo suppressors operate while the break-in feature is trying to force their release. The result is that both receive badly mutilated speech. Both talkers, stop, wonder what has happened and, if their reaction time is about the same, both will start talking together once more. One possible communication satellite system uses 'fixed' satellites, one of which would appear to be stationary. To do this the satellite must be about 20,000 miles above the earth's surface and the transmission time of signals from London to New York via the satellite would be about 240 mS. Using two satellite systems one above the Atlantic to get to North America and another to cross the Pacific to reach Japan would give a total of 700 mS if the terrestrial extensions are included. This is certainly on the high side for commercial speech.

## 13. STABILITY OF WORLD-WIDE CONNEXIONS

All very long circuits must be fitted with echo-suppressors and these effectively eliminate near-singing distortion because when they operate they cut the return path, and they should operate to all except the weakest speech. However, echo-suppressors will not prevent singing because they do not operate until the singing has started. They will certainly stop singing when it has started but soon afterwards it will start once more.

It would of course be possible to use singing suppressors which are quite common on h.f. radio links. They are devices having an action which is the reverse of an echo suppressor. In the idle condition neither talker is connected to the line ; when either speaks he is connected. The major drawback to these singing suppressors is that they clip the initial part of nearly every syllable.

The basic problem is to ensure that there is an adequate margin of stability at every frequency in the audio band for all combinations of subscribers' line and circuits. But as has already been pointed out, the circuits will vary from their nominal value with time and with frequency.

With simple calculations but with many assumptions regarding the standards achieved on world-wide connexions it can be concluded that an adequate margin against singing is provided if the overall loss is not less than $4+\frac{1}{2}n$ db where n is the number of independently maintained circuits connected together. This is also illustrated in Fig. **10** where the equation of the sloping line is $4+\frac{1}{2}n$ db. The United Kingdom contribution to the overall loss of an international connexion will be of the $3\frac{1}{2}+0+0+0$ db pattern whereas the North American contribution follows the $2+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}$ db pattern. This means the nominal loss of a connexion between United Kingdom and North America will fall somewhere in the triangular area to the left (Fig. **10**). The two kinds of transmission plan are quite compatible ; an essential requirement is that international circuits should have a transit loss of 0.5 db.

## 14. OVERALL TRANSMISSION

The C.C.I.T.T. has for many years recommended that the overall reference equivalent of any call should not exceed 40 db. The reference equivalent is a measure of the volume efficiency of a call ; it takes no account of articulation or clarity. It is expressed in dbs relative to a standard local telephone circuit maintained by the C.C.I.T.T. at Geneva which is basically a pair of specified four-wire telephone instruments with no line loss between them. This standard circuit has 0 db reference equivalent and the recommended 40 db simply means that a 40 db, 600 ohm pad inserted between the telephone instruments gives speech that is just satisfactory in the presence of a reasonable amount of line and room noise.

The 40 db limit is broken down into 21.5 db for the national sending reference equivalent and 16.5 db for the national receiving reference equivalent. These allowances assume limiting local lines and include all variations in the loss of the trunks and junctions between the local exchange and the international centre. The allowance for the international circuits in the connexion is 0 db with a variation of $\pm 2$ db. In extreme cases there may be as many as eight international circuits in the new plan, each with a loss of ½ db, and the new C.C.I.T.T. standard should logically be at least 44 db instead of 40 db, unless the national sending and receiving losses can be reduced.

Table 2 shows the figures reported by a few countries for the sending and receiving reference equivalents of their limiting local lines. The losses of the junctions and trunks between the local exchange and the international centre must be added to these figures. These losses depend on the transmission plan of each country. Some of the figures in Table 2 relate to experimental telephones which will not be used in the public networks.

TABLE 2

*Some National Reference Equivalents with Modern Instruments, Limiting Local Lines and No Junction or Trunk Losses*

| | *Send* (*db*) | *Receive* (*db*) |
|---|---|---|
| Austria ... ... | +12 | + 7 |
| Chile ... ... ... | +15 | + 5 |
| France ... ... | +10 | + 2 |
| United Kingdom ... | +12 | + 1 |
| Italy ... ... ... | + 7 | − 1 |
| Japan ... ... | + 9 | + 4 |
| Mexico ... ... | + 8 | + 1 |
| Norway ... ... | +15 | + 8 |
| Portugal ... ... | +10 | + 2 |
| Germany ... ... | +12 | − 1 |
| Sweden ... ... | + 8 | − 7 |
| Switzerland ... ... | + 4 | + 2 |

In the United Kingdom the figures for the instrument and local lines are 12 db and 1 db respectively. These must be augmented by 9.5 db (nominal) as shown in Fig. **19.** Thus the national sending reference equivalent is 21.5 db which is right on the C.C.I.T.T. limit allowing nothing for circuit variations, and the national receiving reference equivalent is 10.5 db, which is well inside the C.C.I.T.T. 16.5 db limit. The recommended difference is 5 db. The United Kingdom difference is 11 db, so it is desirable for 3 db to be removed from one side to the other in the recommendation (or the telephones). Japan and Austria on the other hand have faithfully followed the C.C.I.T.T. recommendation and maintained the correct difference between sending and receiving reference equivalents.

If the two extremes in Table 2 are taken, the overall transmission between subscribers in Sweden and Switzerland is nominally 13 db better in one direction than in the other.

Quite clearly this problem has to be actively studied by the C.C.I.T.T. and the various makes of telephone brought more into line. If this proves impossible another way out of the difficulty is to put differential gain in at the frontier, or, as one country already does, fit asymmetric hybrids in the international trunk relay set. In practice this would mean that an international circuit between two countries having different designs of telephone, instead of being ½ db in each direction of transmission would have, for example, a loss of 3.5 db in one direction and a gain of 2.5 db in the other.

In spite of the differences in efficiencies of telephones, subscribers should be able to talk over a 14 circuit connexion provided the local networks at each end are in reasonably good order, that reasonably good telephones are used and provided all reasonable steps are taken to limit attenuation-frequency distortion, variability of loss, and noise on the international circuits.

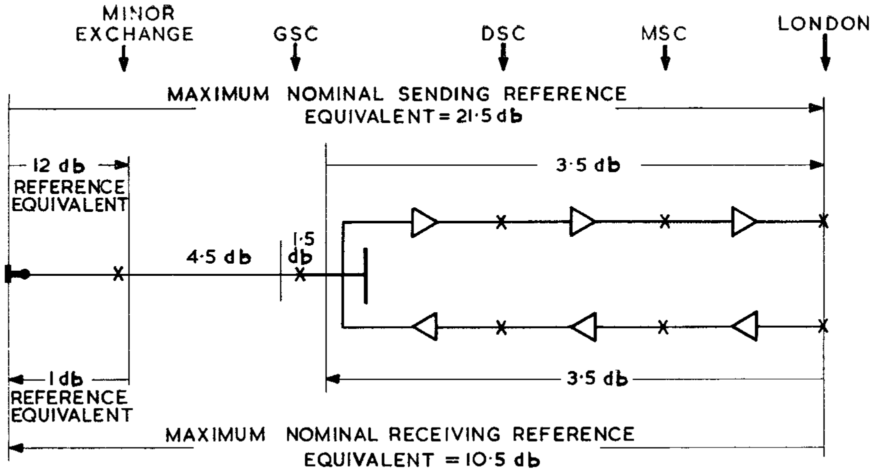
## 15. OTHER SERVICES

Other services, v.f. telegraphs, picture telegraphy and data, for example, will use the same line plant as the public telephone service. As compandors are useful only for telephony it may be necessary to select the least noisy circuits for these other services. It certainly will be essential to keep the overall frequency difference between the two ends of a circuit down to 2 c/s, but this should not be difficult. It may be necessary to provide some extra phase equalization.

## 16. LINE-UP AND MAINTENANCE OF CIRCUITS

The new techniques outlined will call for a new-look by the staff who have to line-up and maintain circuits. As connexions with up to fourteen circuits in tandem and fifteen exchanges are involved transit loss of a circuit is much more important than its loss in terminal service. This means lining-up between switch points and not from the two-wire point of the hybrid. Lining-up between switch points has the added advantages that the nominal losses in both directions can be the same and that the exchange losses are compensated for. Another change, which is long overdue, would be to drop the test level by 10 db below the present standard of 1 mW. It would materially reduce the loading on the transmission systems, but this change of practice cannot be made without international agreement.

There are many new other complications. For example, when compandors are used, the circuit should first be lined-up with the compandors removed. A check should then be made with the compandors in circuit. If the routiner has to test with the compandor in circuit and provide automatic adjustment, then ideally, to avoid tracking errors in the compandor, the adjustment must be made on the line side of the compandor but only half as much adjustment




The Switching Losses of the Minor Exchange are included in the allowance for the Subscriber's Instrument and Line.

C.C.I.T.T. Recommendation: 21.5 db Sending, 16.5 db Receiving.

FIG. 19.—UNITED KINGDOM REFERENCE EQUIVALENTS.

will be needed. The solution might be to render the compandor inoperative during automatic adjustment but this cannot be done when the compandor is at, say, Oban and the routiner is at London. Routining and adjusting TASI circuits clearly would require a special technique.

## 17. CONCLUSIONS

The problems of world-wide telephone transmission outlined in the paper have been studied within the C.C.I.T.T. but much of the experimental work has had to be done by the British Post Office because of its active participation in the CANTAT (Atlantic) and COMPAC (Pacific) submarine cable systems which will provide telephone circuits from Europe to Oceania. When these and other schemes are completed, it will be interesting to compare the results obtained in practice with those deduced from laboratory tests and field trials. Due, however, to the statistical nature of the problems, such comparison will be a complex matter.

## 18. ACKNOWLEDGEMENT

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No. R 2

The Institution of Post Office Electrical Engineers.

# The Control Centre as the Basic Executive Unit

L. G. SEMPLE, B.Sc. (Eng.), A.M.I.E.E.

A Paper read before the North Midland Centre on the 4th April, 1938, and at other Centres during the Session.

This Paper was originally conceived in 1937, and was first presented at Local Centres early in 1938 in the form of notes intended to provoke discussion. It has been re-written for publication and now comprises a brief historical survey of the development of Control Working, a description of procedures now on trial and suggestions for the future which have not yet been given official consideration.

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# The Control Centre as the Basic Executive Unit

## INTRODUCTION.

The paper traces the history of Control Centres from the Fault Control to the present experimental Major Works Control and includes suggestions for the further development of the Control Centre principle and its application to the Telephone Service under Telephone Area conditions. Throughout the paper frequent references will be made to Development Works and to Service Works and a few words of explanation at the outset as to the meaning attached to these titles may avoid confusion in the mind of the reader.

*Development Work* comprises the design, estimating, specification writing and execution of major works which, with few exceptions, provide plant to meet future growth. They are distinguishable from service works principally by their magnitude and by their superior claims to the services of specialists as distinct from engineering executives and by the fact that the need for them is, or should be, evident well in advance of the date for commencement so that they may be designed to conform with a fundamental development plan or policy and executed in accordance with a predetermined programme.

*The title " Service "* covers works of a day-to-day character such as the provision of subscribers' services, maintenance duties and the execution of small and minor works which are comparable in magnitude and scope with Advice Notes and Maintenance Works. It is in the handling of service responsibilities that the primary contacts with the public are made and it is largely by the nature of these contacts that the Department is judged in the public mind.

Each of these main groups is divisible into at least two components, viz.: —

DEVELOPMENT
Major Works

| PLANNING | EXECUTION |
|---|---|
| Long Term Planning<br>Surveys and Estimates<br>Specification writing<br>Budgetary Control | Short Term Planning<br>Field Supervision<br>Day-to-day Control<br>Cost Control |

SERVICE

| Installation<br>Small and Minor Works | Maintenance |
|---|---|

For reasons given later it may prove advantageous in certain circumstances to organise service works on a territorial basis, *e.g.*,

SERVICE

| Territory A<br>Installations, Small and Minor Works and Maintenance | Territory B<br>Installations, Small and Minor Works and Maintenance |
|---|---|

## Origin of Control Centres.

1. *Fault Controls.*

The origin of Control Centres is to be found in the establishment of Fault Controls for directing the movements of mobile workmen operating over a widespread territory with the object of securing prompt clearance of faults at reasonable cost. Such centres have long since established themselves as indispensable units in the Department's organisation with the exception of very sparsely telephoned territory where the detached linemen still hold the field. Even with the latter, however, linemen are grouped under Maintenance Recording Centres having functions similar to those of the Maintenance Controls in all except the hourly control of the linemen's movements.

2. *Advice Note Controls and Installation Centres.*

Following upon a visit to America in 1930, Messrs. Gomersall and Wilby reported that in order to achieve a better speed of completion of Advice Note Works " it should be a principle that installation work should be carried out to completion by an organised Installation Group . . . . . this Installation Group should deal with the installation of simple sets, extensions, subsidiary apparatus and small switchboards as well as with line work . . . . . and should also carry out all removals. Unified control should be obtained by: —

(*a*) concentrating both internal and external installation work under one Inspector ; or

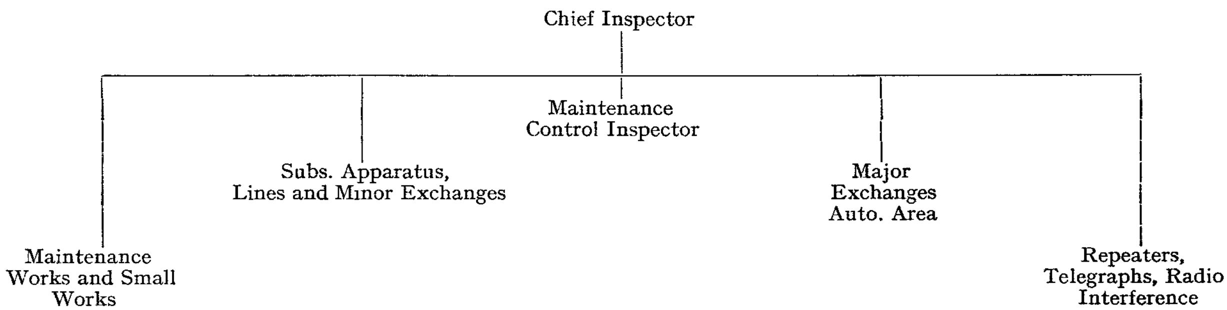
(*b*) placing the Inspectors who are in charge of the external and internal Advice Note work under the control of one Chief Inspector."

3. We find, therefore, that the earlier Controls were set up primarily to speed up service, and statistics prove that much progress has been made towards the attainment of this objective.

4. The existence of Control Centres, even in an elementary form, provided facilities for experiments directed towards the solution of other problems of field forces, a function requiring him to be thoroughly conversant with all the duties which his workmen have to perform and to be competent personally to train and guide them on those duties and so command their confidence and respect.

The arguments revolving around these problems suggested a need for a form of organisation in which an officer experienced in field conditions should take charge of the managerial functions whilst another should concentrate on the field supervision. An early attempt to organise maintenance responsibilities on these lines is illustrated below.

MAINTENANCE CONTROL




management. With the exception of the larger centres organised into internal and external functions, the predominant organisation of the country was on a territorial basis. This form of organisation served its purpose well during the early stages of telephone development, but the introduction of the automatic system and other technical innovations and complexities, together with a very appreciable growth and development of the service as a whole, confronted the Engineering Department with the following problems:

(*a*) the determination of the extent to which a functional organisation could be economically developed ; and

(*b*) the need for relieving Inspectors of routine duties in order that they might adequately fulfil their responsibilities as the supervising officers in immediate charge of the engineering forces in the field.

Probably the most important single fact emerging from the activities of Efficiency Engineers has been a recognition of the need for closer supervision of field operations, such supervision to be directed more to the education and training of workmen and the elimination of wasted effort, than to disciplinary control. It is not necessary to detail the many and varied duties of a territorial Inspector responsible for all types of work within his area or to re-state the case for assisting Inspectors and other supervising officers in the routine work and minor clerical duties inseparable from the effective administration of engineering responsibilities. Much has been done to simplify procedures and to eliminate formalities, but the many increasing demands placed upon the service have overtaken the simplification process, until the Inspector seems less and less able to get to grips with the working conditions and to fulfil his primary function as the supervising officer in immediate control of the

The Control Inspector was required to take charge of the officers employed at the Test Desk and Fault Control positions and to be responsible for the examination of returns and records relating to the maintenance of the area with a view to the detection of unsatisfactory conditions, for originating action to control such conditions, for handling written complaints and for directing linemen's movements in such a manner as to secure prompt and effective clearance of faults. The duties of the remaining Inspectors were to examine the condition of the plant, observe the output methods and workmanship of the maintenance workmen, personally to investigate the more serious repeat faults and to maintain close contact with the workmen.

Developments of this form of organisation have resulted in an acceptance in principle of a division of Inspectors' duties between the Control Function and the Works Function—a line of demarcation particularly useful in its application to Service Works. Although introduced originally to meet densely telephoned areas, it soon become apparent that by grouping several Inspectors' areas and instituting Joint Advice Note and Maintenance Controls, the same form of organisation could be adopted with advantage to meet most rural conditions. Such a scheme was advocated at the first conference of Efficiency Engineers in 1933. The most powerful argument against establishing Control Centres in areas of low telephone density is the cost of keeping an officer at a central point all day to cover a duty which cannot occupy his full time. The argument is applicable to both Advice Note and Maintenance Control Centres but may be met by amalgamation of the two duties under one Control, an arrangement which, in rural areas, possesses definite advantages over separate controls, for the following reasons:—

(i) Variations in the incidence of Fault Complaints and of Advice Note Works favour the employment of dual linemen and mixed duty gangs in rural territories because of:—

(*a*) the difficulty of maintaining an even flow of work for Advice Note gangs;

(*b*) there are savings in ineffective time if Advice Note gangs execute Maintenance Works during the progress of Advice Note work and vice versa;

(*c*) diverting staff from Advice Note work to fault clearance and maintenance and vice versa to meet day to day fluctuations in the incidence thereof;

(*d*) the inefficiency of sending a fitter or a gang a distance of several miles to fit (or recover) subscribers' apparatus to existing line plant at a point where a competent lineman is stationed;

(*e*) at small Maintenance Controls having a staff of no more than one Test Clerk, difficulty is frequently experienced in providing suitable reliefs for test desk duties due to lack of opportunity to afford economical training of other members of the staff. A combination of Advice Note and Maintenance Controls gives opportunities for the combined staffs to become familiar with all duties and thus make suitable reliefs available;

(*f*) under storm conditions when Advice Note Works must defer to fault clearance, there is great value in having the Control of Maintenance and Installation forces centralised at one point.

In addition to the advantages enumerated above in favour of common control of Installation and Maintenance forces in a sparsely telephoned area there is the over-riding consideration that to be of maximum benefit a Control should be located with the Inspectors operating in the Control area. Unless this is achieved much of the assistance which the Control should afford to the Field Inspectors will be lost and there will be an undesirable tendency for the Control to function as a "senior office" rather than as an "assisting office." For disciplinary purposes it may be desirable to outstation one or two Inspectors engaged on service works and such Inspectors probably stand in greater need of a local Control than any others. Usually, one Joint Control is the only type which can be economically justified.

## Summary of Service Control Centres.

We see then that Control Centres, originally introduced to expedite the treatment of Service works, also provide convenient points at which to centralise the miscellaneous routine duties inseparable from the handling of Service works, such duties being performed by junior staff under the direction of an experienced engineering officer and on behalf of Inspectors who are freed to concentrate on the supervision of operations in the field. Having provided machinery to ensure uniform treatment of service matters within a given area and for directing them into the most appropriate channels, it is apparent that the field staff working to such a Control can be organised either territorially or as technical specialists according to the needs of the area. Moreover, the building of numerous small units into a few large units, which is the usual tendency when establishing Control Centres, provides greater flexibility, increases the possibilities of technical specialization and facilitates dilution of field forces with inexperienced labour in times of abnormal development.

On the other hand there has been, in the author's view, a tendency in some quarters to over-centralise as, for example, when one Advice Note Control is instituted to cover the whole of one Telephone Area. Over-centralisation tends to defeat one of the principal advantages of Control working, viz., to permit a reasonable degree of functionalisation without any loss of personal pride and interest in the performance of the team as a whole. The team should be of a size to permit a reasonable degree of functionalisation and at the same time to leave room for the expression of the individuality of each of the more responsible officers. If, as may happen in some places, there is only one natural Control Centre for a wide and densely telephoned area, then, although control of the whole territory may be in one building or even in one room, it is advisable to sub-divide the whole into two or more sub-Controls so that each team may preserve its individuality. This is of some importance also in the compilation of statistics on a Control basis—a subject dealt with later—since if the Control Unit is very large, the Control system of statistics may provide an insufficiently detailed analysis.

## Development Works.

Engineering development work falls naturally into two divisions:—

(*a*) *Planning.*

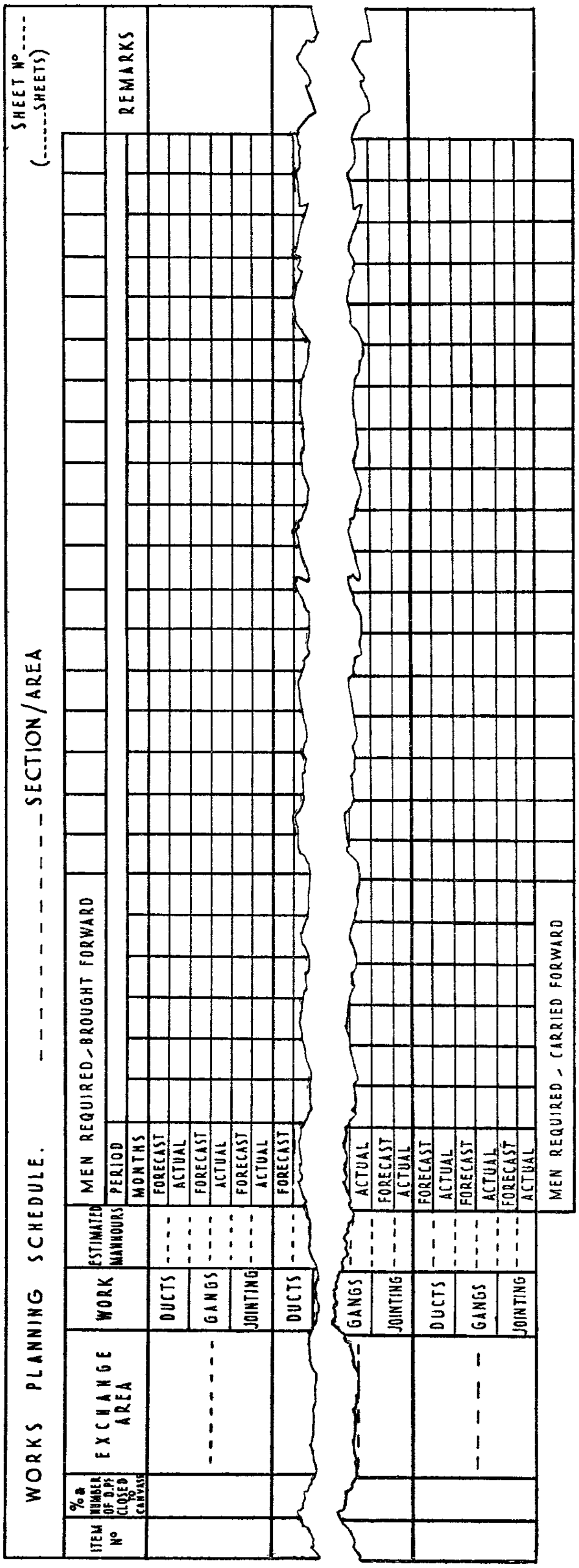
The detailed engineering and preparation of estimates and specifications covering major new construction and rearrangement works.

(*b*) *Major Works Control.*

The execution of the works including preparation of short term programmes, allocation of staff and mechanical appliances, supply and disposal of stores, supervision of methods and results and supplying information for the compilation of accurate accounts and records.

The Planning Group should be aware of all major works, immediate or prospective, and should maintain a progress chart for this purpose (Fig. **1**).

The Development Engineer must work in close co-operation with the Works Execution Engineer, to ensure that his proposals are practicable—but he must also keep in touch with technical improvements, economic factors and long term planning. He is therefore in the position of a liaison officer or intermediary between Headquarters Administration and technical experts on the one hand and the Works Executive on the other and must ensure that the Works Executive is advised through the medium of a specification for each work of the latest engineering practice. It follows that this specification should




CODES TO BE USED.

A Forecast received from D.M.
B Planning of scheme commenced.
C Estimate completed.
D Estimate authorised.
E Duct work commenced.
F Duct work completed.
G Cable work commenced.
H Cable work completed.
J D/H work completed.
K Scheme complete and Records up-to-date.
L W.O. closed.

FIG. 1.

provide complete working plans for the field forces who are to execute the work. These plans must be based upon complete and definite knowledge of the actual conditions which will control the execution of the work—a knowledge to be gained by surveys in the field and a study of complete records of existing plant. In order to avoid duplication of effort in preparing the plans and subsequently in executing the work, the construction forces who are to do the work must be consulted to determine the best method of presenting for constructive purposes, a plan of the work to be done and the best constructive methods to be used in carrying out the work under the conditions which will prevail.

All preliminary work should be completed and the necessary information shown on prints or specifications before the plans are released to the field forces for execution. For example, wayleaves should be secured and details shown on the print—all jointing details should be shown, such as numbering of cable pairs to be brought out, stubs jointed through or terminated.

As far as possible each drawing should be complete in itself; all the information relative to any unit of work as, for example, a section of pole route or underground cable, should be shown on one print, but separate units of work, for example, conduit and cable should be shown on separate prints unless they are interdependent because of construction features.

In general the size of the print should be limited to that which a foreman or workman can handle conveniently in the field and only exceptionally should they exceed 22″ × 34″.

*Construction or Works Control.*

At a conference in 1933[1] attention was focussed on the " inability of the majority of Inspectors to free themselves from the entanglements of correspondence and to devote sufficient energy to the scientific planning and organisation of the works under control " and the setting-up of a Works Planning Group in each Engineering Section was advocated. The duties proposed for the group were " to receive all Works Orders as soon as they are authorised, to decide when and by what gang or working party they were to be erected, to see that all wayleaves were obtained, that stores were requisitioned for delivery at appropriate places and times, to arrange for the preparation of precise instructions and plans which are to be handed to the Foreman before the work is commenced, so that the work as proposed to be carried out in the estimate can be carried through without modification to the original plan and generally to ensure that before works are started every possible eventuality has been foreseen and all possible arrangements made to assist the Foreman to obtain a satisfactory Performance Rating. . ."

It was further proposed that " . . . . A Works Planning Inspector should have mounted on the wall of his room a Works Planning and Progress Indicator upon which would be recorded the constitution and qualification of all gangs and working parties; their previous Performance Ratings and their equipment.

[1] Conference of Efficiency Engineers, 1933. Report of proceedings, 14, 41 and 152.

Against each gang would be shown the Works upon which they are engaged and those allotted to them for execution as soon as present Works are completed. Means would also be provided on the Indicator for showing the manhours expended to date and the corresponding units completed. The Indicator should be so designed that the Works Planning Inspector and the Sectional Engineer can see at a glance how each work stands in regard to performance, when it is likely to be completed, what is the next work allocated to the gang and whether all necessary preliminary arrangements for the starting of that work have been made. . . . . . The Works Planning Inspector will spend the greater part of his time at Section Headquarters, most of the travelling for survey and supervision purposes being carried out by the other Inspectors."

The procedure thus outlined had already been introduced in the Scotland East District with beneficial results and an organisation similar in principle, but differing in detail, developed independently at Leeds. Both organisations were studied and the best features of each were combined, with some improvements, in a draft scheme[2] issued by Headquarters in 1935 to all Superintending Engineers with the suggestion that it should be considered for local adoption. The draft scheme included the following remarks:—

"1. The procedure outlined covers the control, allocation and costing on a performance rating basis of all works (external and internal) exceeding approximately 75 manhours.

. . . . . . . . . . . . .

"4. The procedure in respect of the larger works aims at concentrating Engineering clerical work and other matters at one or two Control Points within a Section with the purpose of securing:—

(*a*) Improved organisation and attention to preliminary detail.

(*b*) Improved supervision and therefore better quality workmanship.

(*c*) Up-to-date Performance Ratings, calculated daily in respect of each working party.

(*d*) Visual indication of the disposition of staff, allocation and progress of works and their respective cost performance.

"5. A Works Control Officer, assisted as necessary by Wayleave Officers, Survey Officers and Writing Assistants, takes charge on behalf of a group of Inspectors of such matters as:—

(*a*) Keeping in touch with the position of all Works from the authorisation stage to the closing stage and, as far as readily possible, dealing with miscellaneous correspondence relating thereto.

(*b*) Requisitioning all Main and Subsidiary Stores items in advance—making arrangements for delivery and temporary storage—checking Delivery Notes against requisitions and generally supervising Stores and miscellaneous transactions.

(*c*) Controlling Motor Transport.

(*d*) Confirming Wayleave negotiations.

(*e*) Supervising the receipt and clerical check (but not certification) of all Progress Reports and Time Sheets of the group and, after certification by the Works Inspector (*i.e.*, the Inspector supervising the execution of the work), their correct disposal.

(*f*) Supervising the preparation of daily Performance Ratings and the upkeep of the Performance Indicator.

(*g*) Preliminary examination of TE 112 on behalf of Works Inspectors—drawing the latter's attention to danger points and obtaining adequate explanations on TE 112A."

It should be understood that the Control Inspector's duties are not intended to relieve Works Inspectors of their responsibilities in such matters as the certification of Progress Reports, critical examination of TE 112S, submission of Departures from Estimate applications, TE 155, nor is it the intention that Works Inspectors shall lose their sense of responsibility for the overall efficiency of the works under their control. The intention is that the majority of the duties outlined above shall be performed by Writing Assistants and/or workmen and that there shall be one Inspector to co-ordinate their efforts and be available constantly to give them guidance, thus releasing the Works Inspectors to spend the majority of their time observing and improving the organisation, quality and efficiency of the work in the field.

Many Works Control Centres have now been established throughout the country to function in accordance with the principles indicated above, although differences exist in the detailed application of these principles to meet local conditions and the views of local officers.

Practical experience of the operation of Major Works Control Centres and other factors have resulted in modification to the original draft and pointed to the need for emphasizing some features more than others. For example, the manhour limit has been raised to 100 manhours consequent upon the introduction of Minor Works Advice procedure, which procedure was itself introduced as a simplification made possible by the existence of Advice Note Controls. Too much attention has perhaps been given to the calculation and plotting of Performance Ratings and not enough to the careful study of works specifications with a view to determining in advance the most satisfactory apportionment of the several parts of a work to the various working units, the size of the economic working unit and the order and method by which the several units shall carry out the work with which they are entrusted.

In the author's view, Performance Ratings need be plotted but weekly and with a continued improvement in supervision and training the calculation of daily ratings could be dispensed with, an overall weekly rating per gang and a weekly cumulative rating per work being sufficient.

*The Basic Executive Unit.*

In the early days of the Service the staff of an Engineer's District was sufficiently small in numbers

[2] Rota 4800 Ed/35. Suggested procedure for Works Control and a Works Allocation and Performance Indicator.

and the class of work sufficiently simple to permit the Superintending Engineer to have a living experience of all its parts so that his control could bear a full and wise relationship to the purpose of the enterprise. Under these conditions and in the interests of clerical efficiency it was natural that clerical work should be centralised at the District Office. As the Service grew, certain clerical duties and an even greater proportion of technical responsibility was devolved upon the Sections. Of recent years the growth of the Service and the demands made upon it, have now so increased the responsibilities of Sectional Engineers that effective executive control can only be exercised at a lower level.

Effective executive control requires that the officers concerned shall have readily available full information relating to the progress and performance of works and workmen under their control. Since the preparation of such information is bound up with essential field accounting and statistical requirements, it follows that advantages should accrue from associating with the Control the clerical forces engaged on field accounting and statistical work.

*The Major Works Control as an Executive Unit.*

In 1937 an experimental procedure devised by a Headquarters' Committee was introduced in the Scottish Region which aimed at concentrating at the Works Control Centre many of the duties hitherto performed by Clerical Officers in the Superintending Engineers', Sectional Engineers' or Area Managers' Offices, together with simplifications in procedure which such devolution makes possible, viz.:—

(1) Receipt, clerical check of Progress Reports and Time Sheets; summarisation of units and manhours; and the calculation of Performance Ratings for individual working parties, for each major work and for the Control Centre as a whole.
(2) Preparation and upkeep of a weekly summary of expenditure (TE 112 revised), of a History Sheet (TE 112A revised), and a Stores Summary (TE 118).
(3) Requisitioning stores in accordance with estimate and/or supplementary instructions.
(4) Handling departures from estimate.
(5) Check of Contractors' accounts against Diary Pages.
(6) Upkeep of information on Control and Performance Indicator Panels.
(7) Preliminary closing of Works Orders.

All the information, including that referred to above, relating to any one major work is available for inspection at any time by any interested officer.

The opportunity was taken to introduce other modifications to existing procedure such as summarising manhours in bulk under—

(*a*) Providing, Recovery, Shifting and Ineffective in accordance with the standard practice for A.N. and Small Works—abandoning the allocation of manhours to individual works operations (Item numbers).
(*b*) Simplifying TE 155 (Labour excess) and TE 68 (Stores excess) procedure.

Each Field Inspector is required to submit a Daily Works Report describing briefly any item of interest observed during the course of his visit to the field forces and including information regarding actual or anticipated departures from the authorised plans and estimate.

A statement on the Daily Works Report of the causes, nature and extent of departures, either actual or anticipated, is all that is required from the Field Inspectors since the procedure provides that the Control Office shall arrange for the necessary authorities, credit the Works Order therewith and arrange for the supply of extra stores automatically. If the excess is for additional plant (stores), then it is not necessary for the Field Inspector to state the number of manhours since the Control Office will assume, unless the contrary be stated, that the additional plant can be erected at the estimated Performance Rating of the original estimate.

In addition to the foregoing simplification of D.F.E. procedure, the Daily Works Reports serve two other purposes.

(*a*) Information contained in them is transferred in precis form to the History Sheets (late TE 112A) for the Works concerned, and provides an up-to-date statement of the progress of the work and of all the factors affecting the execution of the work. Such information gives a valuable guide to the accuracy and soundness of the original proposals and provides adequate and immediate information regarding departures.
(*b*) The Daily Works Reports themselves are filed by Field Inspectors' Groups and scrutiny of these reports gives a fair indication of the interest and ability displayed by these Inspectors on field supervision. Lengthy and verbose reports are not required; the intention is that all really valuable information shall be given in as few words as possible.

The two most outstanding benefits so far derived from the scheme are a considerable increase in the amount of time available to Field Inspectors for field supervision and the ease and promptitude with which Works Orders are closed. The time increase is of the order of 15-20% over the former Major Works Control procedure and considerably more than 20% when compared with pre-control conditions. Inspectors and Clerical Officers engaged on the operation of the new procedure are unanimously in favour of it.

It should be noted that the strictly accounting functions as distinct from statistical and detailed costing functions remain as a separate unit of the Telephone Manager's Office.

The "Scottish experiment," as it has come to be called, has been examined by many officers and criticised from many angles and a number of amendments have been suggested and are receiving official consideration. There appears, however, to be unanimous approval of the underlying principle of co-ordinating all related functions at a lower level than the Sectional Engineer and in the direct association of clerical staff with Works Inspectors, and further experiments incorporating some of the amendments are to be made at Reading and Guildford.

## Basic Executive Units.

To this point the paper has been an historical survey of the development of the Control Centre. The remainder of the paper is devoted to an expression of the author's personal views on the further development of these centres. None of these views has as yet received consideration in official circles and indeed the author is aware that they do not find favour in some quarters.

In the experimental Major Works Control organisation we see a step towards the co-ordination of related functions at lower levels than hitherto, that is, in the direct association of clerical duties with Control Centres and therefore with the Works Inspectors who constitute the eyes and ears of the Control. The next step is the application of the same principles to Advice Note and Maintenance Controls. The objective of the Post Office re-organisation has been interpreted as elasticity and efficiency in the Post Office organisation and responsiveness to public demands and needs. This objective it expects to attain in the first place by a substantially increased measure of decentralisation —a devolution carried to the lowest level compatible with efficiency and in this connection the first report of the Committee on Metropolitan and Regional Organisation says: "In approaching the subject of re-organisation we have thought it well to consider first the basic executive units of the system. It is at this level that the primary contacts with the public are made in respect of Service and the handling of enquiries and complaints and it is largely by the nature of these contacts that the Department is judged in the public mind."

It would be difficult to describe more aptly and in so few words the functions of Advice Note and/or Maintenance Control Centres in their relation to the Engineering Department's organisation. They *are* the basic executive units of the service side of our work providing the unit of organisation upon which the efficiency of the Service depends.

### *The Installation Control as an Executive Unit.*

The four duties involved in the provision of a new installation are Sales Representative, Traffic Officer, Engineer and District Manager's Accounts Section. Without minimising in any way the importance of the functions of the other three the responsibilities of the Engineer are of the first importance. Briefly, it is the responsibility of the Engineer to provide the service as quickly as possible, in the most economical manner having regard for local amenities and in such a manner as to give lasting satisfaction to the subscriber. The means by which this responsibility is fulfilled involves the allocation and availability of spare plant, a close control over the movements of the staff, a quick appreciation of what is involved in the provision of any given service, a system of quality inspection, and the maintenance of friendly relations with the local authorities, to mention only the most obvious duties.

In most centres there is already an Advice Note Control Centre which exercises these responsibilities on behalf of the Sectional Engineer and these centres constitute the real basic executive units for the provision of subscribers' services. The desired unification of duties in the public interest can best be achieved by locating Sales representatives and Advice Note issuing and closing clerks at these Control Centres. In addition to more complete information regarding the requirements of a new installation, the regulation of canvassing, closing of areas, etc., would more easily be achieved.

In the author's view the unification would be even more complete if it were made a matter of future policy that a not inconsiderable proportion of sales representatives should be recruited from the ranks of the Engineering Department—preferably those entering the Service as Youths-in-Training after a secondary school education. If necessary, youths could be especially recruited with this object in mind and the benefits and economies which would result from sales representatives having an intimate knowledge of what is involved in the provision of a subscriber's service would be far reaching.

The author does not suggest that the sales representative should necessarily be under the control of the Engineering Officer in charge of the Control Centre or vice versa, but rather that the public should be able to look to one Centre for information on all matters appertaining to the provision, alteration or removal of telephone service and that the Sales and Engineering Officers for a given area should work as a team, each member of which has a particular responsibility to his own superior officer. In the ultimate, each Advice Note Control Centre would be self-contained, maintaining its own records and compiling its own returns for which it would have the assistance of such clerical staff as the work justified.

With the extension of automatic working the functions of the Traffic Officers have become more closely allied with those of Engineering Officers and investigation would probably shew that much of the detail of the Advice Note responsibilities could equally well be performed by staff at Installation Controls.

### *The Maintenance Control as an Executive Unit.*

Telephone Areas' boundaries have been determined as far as possible to conform with the natural development of the telephone network, *i.e.*, to be co-terminus with group centre boundaries so that the territory controlled for traffic purposes from one group centre should be wholly contained within only one telephone area. Maintenance Controls should therefore normally be located at a group centre or auto-manual switching centre (but not necessarily at every group centre) which, under fully automatic conditions, will be the only centre at which assistance traffic will be handled.

The staff of a large Engineering Maintenance Control Centre already comprises a team of more or less specialist officers and there appears to be no good reason why there should not be added to it one or more officers well versed in the service duties at present performed by the District Manager's Traffic Staff only. As in the case of the proposed Installation Office, the unit would at the outset comprise a staff working as a team in the interest of the subscribers, although guidance and instructions on general policy would be determined by the Telephone Manager with the assistance of his expert advisers, each of whom would also function in an inspectorial capacity in his own particular sphere.

*Joint Installation and Maintenance Controls as Executive Units.*

The existence of a Joint Control will generally imply that the territory controlled is sparsely telephoned and the volume of work is not great. The Control Staff will, therefore, be few in number and some difficulty may be experienced in devolving commercial and traffic responsibilities. Nevertheless, it should be possible to effect some degree of devolution in such matters as the acceptance of straightforward orders and handling complaints in order to maintain at all centres a policy of maintaining close personal contact between subscribers and the officers of the telephone service who possess an intimate knowledge of the subscribers' requirements and of the service rendered to him.

*Development and Planning Unit.*

The design of a fundamental plan for the provision of plant to meet future growth involves Traffic studies, Sales studies and Engineering design, and a combination of these duties into one central unit for each Telephone Area should be the most effective way of co-ordinating the various activities.

Instructions on the preparation of maps by the Engineering Staff, for the purposes of Block Surveys by the Sales Staff, emphasize the need for the closest collaboration between the two staffs so that the

EASTHAMPTON SECTION. MAINTENANCE CONTROL LOCATED AT ROKING

N. F. CHEAM. CHIEF INSPECTOR.

CODES [square with figure] = NUMBER OF QUALIFIED MEN NECESSARY TO EFFICIENT MAINTENANCE OF LOAD.

[crossed square] = UNSUITABLE FOR TRAINING.

[divided square] = { LEFT HAND COLUMN = SCHOOL TRAINING; RIGHT HAND COLUMN = FIELD TRAINING AND EXPERIENCE. } UPPER SQUARES = HIGHLY QUALIFIED. LOWER SQUARES = QUALIFIED.

ø = FOR U S W^s ——— QUOTE DATE OF FIRST SKILLED CERTIFICATE

| LOAD Nº | INSPECTOR | RELIEF INSPECTOR | S.W.I. | DUTY Nº | RELIEF S.W.I. | WORKMEN | RANK | ø SENIORITY | TRAINEES | RANK | HEADQUARTERS | DATE OF RETIREMENT | INSPECTORS COURSE | INSTRUCTOR | CERTIFICATES Nº & GRADE | PANEL | LINES | SUBS APPARATUS | HOUSE TELEPHONES | PHONOGRAMS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1P | | | | | | | | | | | | | | | | | | | | |
| 1F | | | | | | | | | | | | | | | | | | | | |
| | A. JONES | | | | | | | | | | RG | 60 | | | 3/1 | | | | | |
| 2P | | | | | | | | | | | | | | | | | | | | |
| 2F | | | | | | | | | | | | | | | | | | | | |
| | | P. SMITH. | P. SMITH. | A6. | | | S.W.1. | 47 | | | RG | 68 | | | 3/1 | ✓ | | | | |
| | | | (Control | | S MORRIS | S MORRIS | U.S W. | 6/36 | | | RG | 73 | | | 2/1 | ✓ | | | | |
| | | | Group) | | | | S.W 2 | 135 | | | RG | 60 | | | | | | | | |
| | | | | | | | | 5/37 | A. THOMSON | Y.IN.T | RG | 78 | | | | | | | | |
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| 3P | | | | | | | | | | | | | | | | | | | | |
| 3F | | | | | | | | | | | | | | | | | | | | |
| | | | T HARDING. | A1. | | | S W1 | 63 | | | RG | 60 | | | 2/2 | ✓ | | | | |
| | | | (Main | | R. JACKSON. | R JACKSON. | S W 2 | 230 | | | RG | 70 | | | | ✓ | | | | |
| | | | Auto | | | G WELLS. | S.W.2 | 291 | | | RG | 70 | | | 2/2 | | | | | |
| | | | Group) | | | S. HUDSON | S.W.2 | 299 | | | RG | 72 | | | | | | | | |
| | | | | | | | | 7/38 | J. WILSON. | Y.IN.T | RG | 79 | | | 1/1 | | | | | |
| 6P | | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| 6F | | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| | S. VEALE | | | | | | | | | | RG | 50 | | | | | | | | |
| 7P | | | | | | | | | | | | | | | | | 4 | 4 | | |
| 7F | | | | | | | | | | | | | | | | | 4 | 4 | | |
| | | | V. CHURCHILL. | A12a | | | S.W.1 | 39 | | | RG | 65 | | | 2/1 1/2 | ✓ | | | | |
| | | | (Roking Subs and | | | N HAMILTON. | S.W.2 | 121 | | | RG | 58. | | | | | | | | |
| | | | InnerArea) | | P. SHARPE | P. SHARPE | S.W 2 | 207 | | | RG | 71 | | | 3/1 | ✓ | | | | |
| | | | | | | J. WHITE | S.W.2. | 304 | | | RG | 72 | | | | | | | | |
| 8P | | | | | | | | | | | | | | | | | 4 | 4 | | |
| 8F | | | | | | | | | | | | | | | | | 4 | 4 | | |
| | | T MITCHELL | T. MITCHELL. | A12a | | | S.W1 | 57 | | | AY | 62 | | | 3/1 | ✓ | | | | |
| | | | (Aynton Area) | | A. HARRISON | A. HARRISON | S.W2 | 241 | | | AY | 63 | | | 2/1 1/2 | ✓ | | | | |
| | | | | | | B ANDERSON | S W2 | 170 | | | PK | 56 | | | | | | | | |
| | | | | | | W LITTLE. | S W2 | 257 | | | SM | 66 | | | | | | | | |

TWO LOADS SHOULD BE SHEWN FOR EACH GROUP OF WORKMEN (a) PRESENT LOAD (b) ANTICIPATED LOAD REQUIREMENTS 2 YEARS HENCE.

FIG

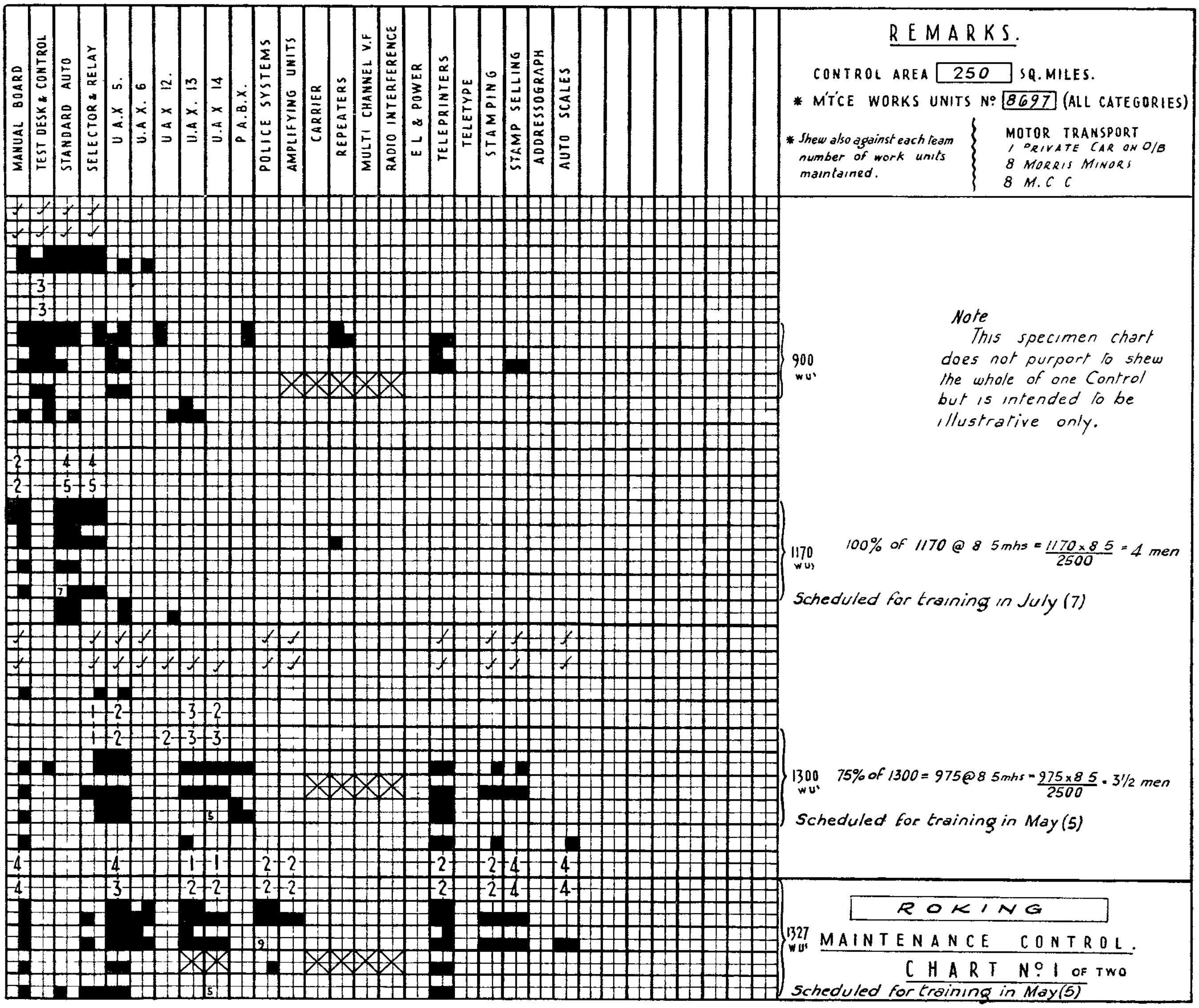
large expenditure on underground plant is properly regulated. In the author's view a Development and Planning Group might, at the outset, comprise both Engineering and Sales development officers working as a team, and future recruitment and training should aim at a body of men versed in both duties and competent to carry a scheme through in its entirety. If the Sales development officers were more intimately aware of the problems involved in the lay-out of line plant and if Engineering development officers were more in touch with the factors which influenced the development forecasts for a given area, the resultant scheme should more nearly approach its purpose, viz., the provision of adequate, but not excessive, plant to meet future development.

Similarly, there is much to be said in favour of combining the Traffic Officers engaged in Traffic design with the Engineering Officers engaged in converting that Traffic design into an equipment specification.

*Control Statistics.*

If the Control Centre is to be treated as the basic executive unit, then clearly performance statistics of both quality and quantity must be available on a control basis.

Such statistics have been available for a number of years in respect of the maintenance performance of at least one Engineering District and recently the whole of the Engineering Department's maintenance statistics were revised to put them on a control basis.




2.

For the measurement of local performance and for the purposes of local supervision, control statistics provide a better analysis than Section figures for each maintenance sub-division. The adoption of control costing has helped to make possible the bulking of maintenance manhours hitherto kept in separate groups such as the six groups for Subscribers' Apparatus on different types and sizes of exchange.

The one criticism to which any new form of organisation exposes itself is the cost of implementing it as compared with the savings it is designed to secure. The absence of costs of Engineering Supervising Officers, Control Officers, Clerical Officers and of Motor Transport engaged on specific duties has made it difficult in the past to obtain a true picture of the overall costs of any one form of organisation or of any one team.

A system of comprehensive costs per Control has been devised and is being tried experimentally in several areas. By this means it is possible to determine the overall costs, inclusive of direct labour, supervisors, associated control (including clerical) staff, motor transport and subsistence for each Control team which will permit of true cost comparisons, not only between comparable Controls but also between one form of organisation and another.

The value of comprehensive costs, in principle, is indisputable, but it is perhaps not too much to say that an analysis on a Control Centre basis is the only practicable method of compiling such costs. To prepare and make use of such statistics on an Area or Section basis is almost impossible since they would comprise a summary of the expenditure incurred under the control of numerous supervising officers, working independently and the performances of individuals would not be readily obtainable. Variations in types of work add still further to the difficulties. Control Centre statistics, however, represent the performance of a team and are therefore a measure of the efficiency of local organisation and supervision as well as of labour and transport expenditure.

*Personnel.*

A team of workmen working to a Control Centre constitute a convenient unit on which to determine staff requirements. The numbers and qualifications of the workmen must be related to the immediate and prospective works load and such loads divide naturally between Controls, each type of Control representing a type of work and requiring qualifications dissimilar from those of other Controls. This statement should not, however, be interpreted as preventing or prohibiting interchange of staff between Controls, but rather as drawing attention to the fact that such changes should be kept at a minimum.

Fig. **2** is a Staff Control Chart for a Maintenance Control which has the undermentioned objects in view:—

1. To provide a means whereby maintenance loads may be scheduled in such a manner as to indicate the qualifications necessary for the efficient management of the load.
2. To provide a means of scheduling the staff *vis-à-vis* the load requirements and thus to determine—
   - (*a*) the extent to which the staff possess the qualifications necessary to the management of the load;
   - (*b*) the need for additional training of existing staff to remedy deficiencies revealed by (*a*);
   - (*c*) to guard against over-training of any one officer to the detriment of others and to effect economies in training expenditure;
   - (*d*) the need for additional trainees, *i.e.*, reserve staff, to meet future developments such as may arise from growth of or changes in type of plant, promotions, retirements, etc.

The workmen comprising the Maintenance team are divided into convenient Maintenance load groups and in each of the columns is entered a figure to represent the number of workmen who should be qualified in the subject concerned in order that the load may be efficiently covered. Two figures are quoted, the first (P) to indicate present requirements and the second (F) to indicate requirements two years hence.

Opposite each man's name and in the appropriate columns code markings are made to indicate the qualifications of each man.

## Accommodation

*Maintenance Controls.*

In what follows the term "Control" includes the control staff, the control inspector and the field inspectors associated with the control.

For obvious reasons, *e.g.*, fault reporting and testing, maintenance controls are best located at the group centre exchange or switching centre of the control area and adjacent to the main frame. Since, however, it is undesirable that a control room should form part of an apparatus room it follows that the main frame and the maintenance control should occupy a room separate from, but close to, the apparatus room.

Provision should be made for the accommodation of traffic staff within the same building although it may be difficult to locate them with, or even adjacent to, the control room.

*Installation Controls.*

An installation control in the same town as the Area Manager's Office is probably best located in that Office together with the Sales Staff. Subsidiary installation controls at outstations should occupy rooms in the same premises as the local maintenance control even although they may be operated as separate and distinct controls.

*Development (Planning) Units.*

Generally, there will be only one planning unit within an area, although such unit may be sub-divided into internal and external functions. This unit should be closely associated with the Traffic Design and Sales Development Staffs, with the Accommodation Duty, also with the Drawing Office and Plant Records Duty.

In some areas depending upon the qualifications of the existing staff and the volume of internal and external work, respectively, it may be advantageous to group the development and execution work as follows:—

External Works Control

External Engineering Development and Sales Development Staff

Internal Development and Works Control and Traffic Design

*Major Works Control.*

Sufficient accommodaton should be provided within the major works control to meet the requirements of the clerical forces intimately associated with such work and the remaining engineering clerical staff should be housed in an adjacent room. When planning the layout of a major works control it should be borne in mind that a part of the time of some of the clerical staff should be devoted to giving direct assistance to inspectors or groups of inspectors in such

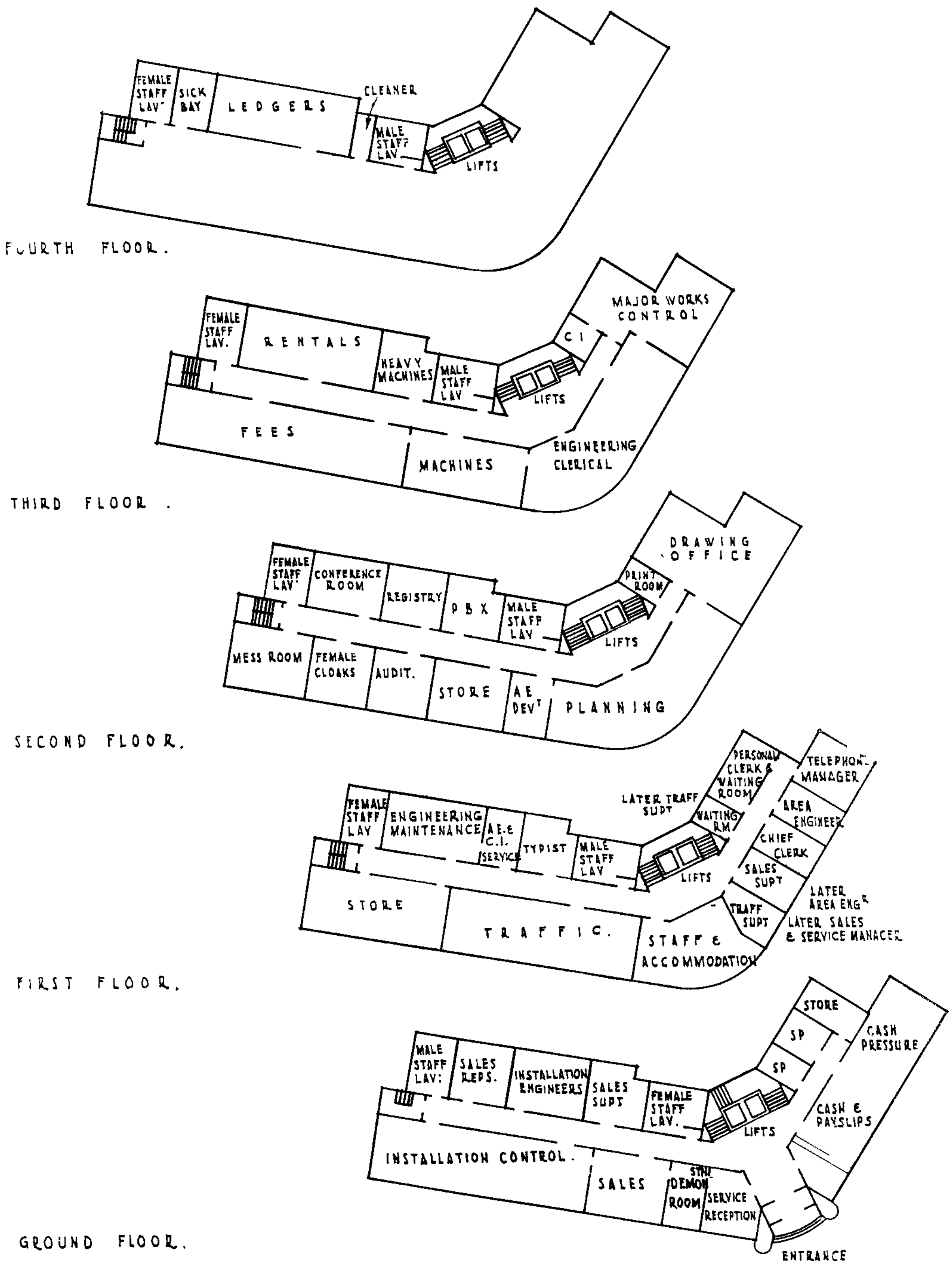



Fig. 3.

matters as the handling of the daily correspondence, answering telephone calls, filing, etc., as well as the indirect assistance afforded by the clerical group as a whole. It is desirable, therefore, that at least one clerical assistant should be allotted to each group of three or four field inspectors for this direct assistance and should be seated at their group of tables. This direct personal assistance, however, will not normally be a full-time job and the remainder of her time can be occupied with a routine job associated with the main clerical staff within the control.

The layout of accommodation in Area Managers' Offices has been determined in the main, and as far as circumstances would permit, on the lines indicated, and Fig. **3** is given as an example.

## Conclusion.

No organisation can be satisfactory which does not make provision for variations between one place and another, in the qualities and capabilities of existing staff, telephone density, etc. It is the author's view that the principles of control working leave ample scope for ingenuity in their application to particular circumstances without departing from the fundamental principles which may be re-stated as follows:—

1. Service Duties should be separated from Development Duties.
2. Service Controls may be divided into—
   (*a*) Installation Controls,
   (*b*) Maintenance Controls, or
   (*c*) Joint Installation and Maintenance Controls.
3. Development Control may be divided into—
   (*a*) (i) Planning and Development (internal and external),
   (ii) Major Works Control (internal and external),
   or (*b*) (i) Planning and Development (internal only),
   (ii) Major Works Control (internal only),
   (iii) Planning and Development (external only),
   (iv) Major Works Control (external only),
   or (*c*) (i) Planning and Major Works Control (internal only),
   (ii) Planning and Development (external only),
   (iii) Major Works Control (external only).
4. Each control should be a self-contained unit comprising all the technical and clerical forces necessary to the fulfilment of its functions and equipped with statistical and other data necessary to the measurement of its performance.
5. Within each control the organisation should be such as to ensure that sufficient time is available for adequate supervision of the field forces and that such supervision is directed as much towards the guidance and encouragement of staff as towards inspection of quality and output.
6. No control should be so large that the supervising officers completely lose their individuality.

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