The Post Office Electrical Engineers' Journal

VOL 73 PART 2 JULY 1980

VOL 73 PART 2 JULY 1980

Contents

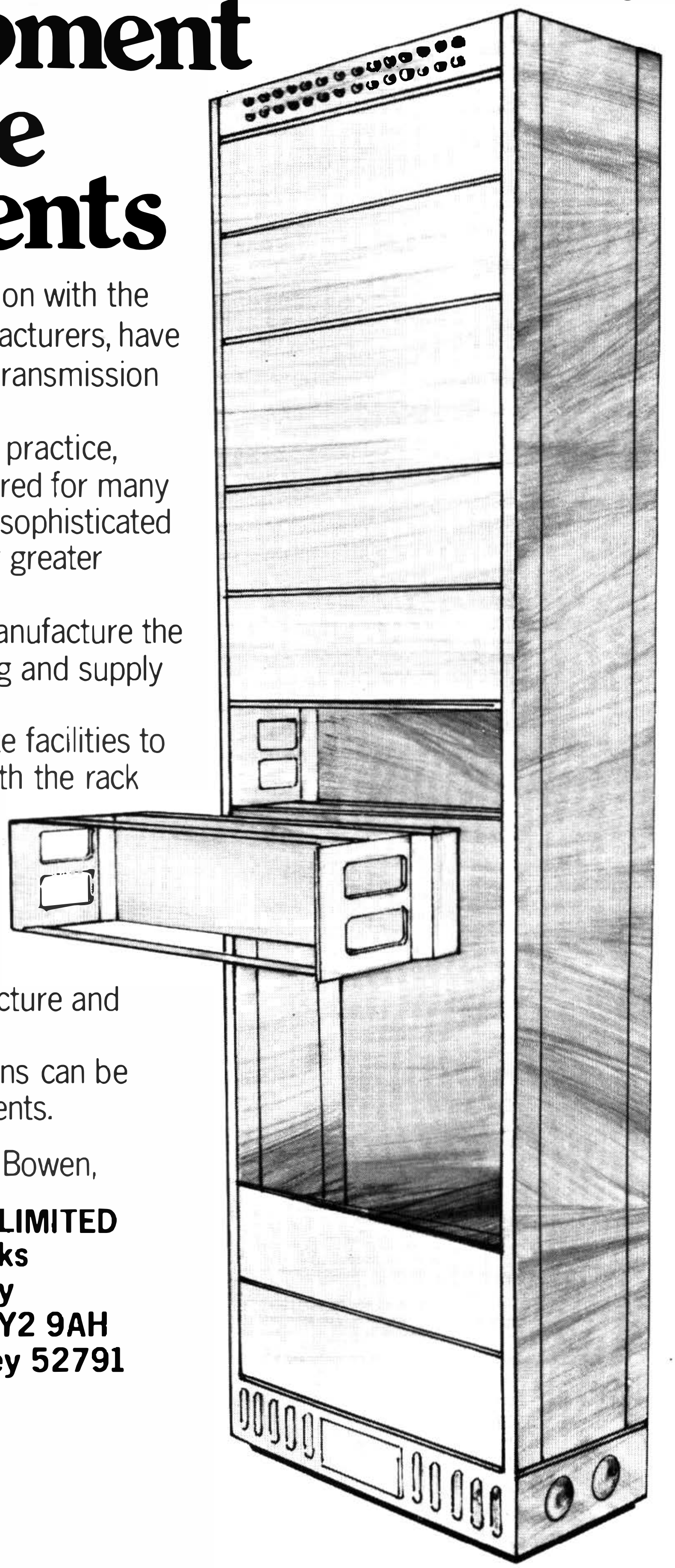
Published in April, July, October and January by *The Post Office Electrical Engineers' Journal*,
2–12 Gresham Street, London EC2V 7AG.

Price: 70p (£1.05p including postage and packaging). Orders by post only.

Annual subscription (including postage and packaging): home and overseas £4·20.
(Canada and the USA $10·00.)

Price to British Post Office staff: 48p.

Let Herman Smith supply your Equipment Practice requirements



The British Post Office, in conjunction with the telecommunication equipment manufacturers, have developed a new racking system for transmission and other equipment applications.

This is to replace existing 62 Type practice, which Herman Smith have manufactured for many years. It will house equipment in very sophisticated miniaturised forms and will offer a far greater packing density.

Herman Smith on their part will manufacture the metalwork for this new type of racking and supply any company or public body.

The company has full and adequate facilities to make and inspect this equipment—both the rack and the incorporated shelves—to the exacting requirements.

At present, the company is supplying 62 Type wired assemblies and racks to the Post Office and is fully approved for Post Office manufacture and also to 05/24 M.O.D. standards.

Cabinets and sheetmetal fabrications can be made to customers' special requirements.

Enquiries to Peter Bowen,

HERMAN SMITH

HERMAN SMITH LIMITED
Cinder Bank Works
Netherton, Dudley
West Midlands DY2 9AH
Telephone: Dudley 52791

Having found a good home for our one-millionth TXE4 electronic line, in our

KING
EMPLOYMENT
Agency
OFFICE
STAFF
levens
TO LET
FIRST FLOOR
464-7197
AKASH
TANDOORI
RESTAURANT
SHOE BOX
Good Shoes for Less
CLARKE
for wools
AMERICAN
HAMBURGER

THE MICROWAVE RADIO FOR EVERY USE

*Selected by the Post Office. Again!

Frequency Agility
The TCM-6 is tunable across each band from 1.7 to 15.35 GHz. Change bands by plug-in RF module replacement.

Fixed Link or Portable
Simplex, duplex and diversity operation in tripod, tower or rack mount configuration.

Proven Operation
Used worldwide from arctic to desert environments by major television and telecommunications administrations.

Full Performance
Color video with FM or digital subcarrier channels, 1800 FDM voice channels, 34 Mb/s digital data or wideband radar video.

* TerraCom has been awarded Post Office contract 580678DD for the supply of 50 TCM-6 portable, tunable microwave links. The equipment will be used for telephony and television transmissions in the 2 GHz, 2.5 GHz, upper 6 GHz and 12 GHz bands. This award follows a previous Post Office contract awarded in 1979 for 22 TCM-6 links.

TERRACOM®

Loral Corporation
9020 Balboa Avenue San Diego, CA 92123 U.S.A
Phone: (714) 278-4100 TWX: TERRACOM SDG 910-335-1202

The Post Office Electrical Engineers' Journal

Institution of Post Office Electrical Engineers

The Secretary of the Institution of Post Office Electrical Engineers (IPOEE), in his report in the April 1980 issue of the *Journal*, drew attention to the fact that 1981 will mark the 75th anniversary of the IPOEE. A somewhat more significant event planned for 1981 is the establishment of the new British Telecommunications Corporation to take over the telecommunications business of the British Post Office. This separation of the postal and telecommunications functions will have a profound effect upon the future of the Institution and of the *Journal*.

The bulk of the Institution's membership is employed in telecommunications engineering and hence a title referring exclusively to "Post Office Engineers" will no longer be appropriate. The choice of a new title for the Institution poses a difficult problem which cannot be solved until certain fundamental questions concerning the separation of the Postal and Telecommunications Businesses have been answered. The Council of the IPOEE has concluded that, for the present, no action can be taken. The matter will be kept under review and proposals to introduce a new title will be put to the membership for agreement, in the form of proposed changes to the Institution's rules, as soon as this becomes possible.

Only when a change of title has been agreed can the change be reflected in a new title for the *Journal*.

RETIREMENT OF MR. J. F. P. THOMAS FROM CHAIRMANSHIP OF COUNCIL

Although Frank Thomas's services to the Post Office are far from at an end, he retired as Chairman of IPOEE Council at the same time as his formal retirement from the British Post Office (BPO) in May 1980.

Frank has been Chairman of Council, and of the *Journal's* Board of Editors, since 1972. It has been a turbulent time for the Institution. Inflation has driven us to revise our subscriptions more frequently than we would have liked and—during one particularly unhappy period—to cut back on some of our activities. Our rules have needed constant revision to keep pace with changes in BPO organization and titles; we have initiated the formation of a national telecommunications museum; and we have started the move towards an association with our Continental engineering colleagues in FITCE.

Frank Thomas has presided over all these changes with unflappable equanimity and robust good humour. He has coaxed and cajoled Council into flights of unsuspected imagination. He has delivered innumerable speeches combining inspiration, earthy good sense and rollicking farce. But perhaps, most of all, he would like to be remembered for his decision to take Council out to the Centres rather than be confined to London, and so involve local experience in Council's deliberations.

Frank's guidance and active enthusiasm have been rewarded by a constantly growing Institution membership and an ever widening range of activities. All Institution members wish him well in his future endeavours; we will miss him very much.

D. WRAY

Telephony Transmission Standards in the Evolving Digital Network

K. R. HARRISON, M.SC., B.SC.(ENG.), C.ENG., M.I.E.E., A.C.G.I.†

UDC 621.391:621.395

The introduction of digital transmission and switching methods in the UK telecommunications network presents systems designers and planning engineers with a complex assortment of network problems, some of which require unusual solutions. This article discusses a selection of the problems (with specific reference to the change-over from analogue to digital working), and explores the possible results of the envisaged changes on telephony. The assumption is made that local telephone circuits will broadly retain their present analogue form.

INTRODUCTION

The era of change from analogue to digital techniques in the transmission and switching areas of telecommunications networks has brought many problems and challenges to system designers and network planners. Not the least of these is apparent in the field of transmission standards where, for the first time in telephony history, it is possible to foresee the age when it will be a viable proposition to place most national and international telephone calls in the loudness range which, subjectively, people find desirable.

On the longer distance calls, analogue transmission techniques generally produce their fair share of faint but noisy connexions, while local calls are often too loud. The UK telephone network is not exempt from such impairment, for it is merely a reflection of the best cost/transmission quality balance that can be obtained within the state of the technology that is available at the time.

Although telephony remains the major user of the analogue network, a number of services have been derived; for example, the Datel and radiopaging services. Other services, such as Telex and the packet switched data service, are provided by making use of the main transmission media only.

With the introduction of digital transmission and switching techniques, it is the intention of the British Post Office (BPO) to move towards the establishment of an integrated services digital network (ISDN)[1]. The ISDN will be capable of supporting a wide range of services within the framework of one common network, thus making maximum use of resources.

This article considers only telephony transmission standards, although reference is made to other services where appropriate insofar as the network needs to be dimensioned to anticipate their requirements.

With the advent of digital transmission and switching systems the economics of network provision have altered considerably and it is now possible to make use of transmission facilities that were, effectively, hitherto unavailable. It was therefore essential at the start of the design period to undertake a complete review of the transmission attributes of the telephony network with the object of selecting those that could be reasonably and economically incorporated into it in the forthcoming digital era. By its very nature this review was an iterative process, with the transmission standards engineer seeking optimum arrangements and the operational departments looking for minimum capital outlay. Inevitably, such studies are complicated by the need for simple interworking procedures between the old and the new technologies for a period of several decades and the necessity to continue to observe international agreements throughout. Extensive use was made of computerized network-modelling facilities, without which the network design process would have been longer and more costly. For the most part, this article records the outcome of the studies insofar as decisions have already been taken; various other transmission strategies were investigated and, subsequently, rejected.

† Network Strategy Department, Telecommunications Headquarters

THE EXISTING TRANSMISSION PLAN

Because interworking considerations place major constraints on network and equipment design, it is first necessary to examine briefly the existing network to ascertain its attributes. The present transmission plan[2,3] is oriented to analogue transmission and switching systems; the only significant penetration of digital equipment is in the junction network[4] (see Fig. 1).

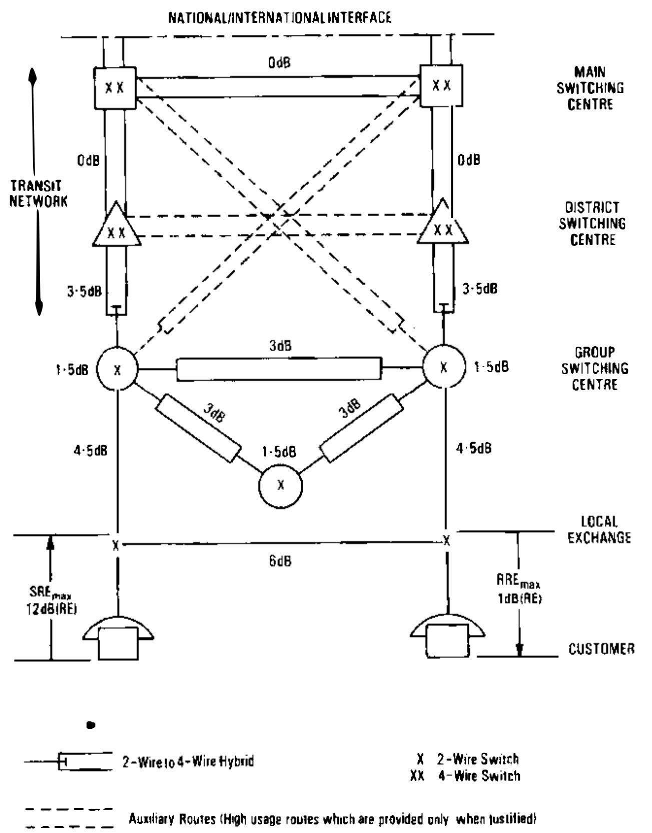
Allowing 1·5 dB for switching, cabling and mismatch losses at each group switching centre (GSC), the nominal maximum 1600 Hz loss between 2 local exchanges is 19·5 dB (via 2 GSC to GSC links). In terms of acoustic-to-acoustic loss between customers, the maximum nominal overall reference equivalent (NORE) for the network is the sum of the send reference equivalent (SRE), the maximum loss between local exchanges and the receive reference equivalent (RRE); that is,

$$\text{NORE}_{max} = \text{SRE}_{max} + 19{\cdot}5 + \text{RRE}_{max}$$
$$= 32{\cdot}5 \text{ dB (RE)*},$$

a value which is often rounded to the well known 33 dB (RE) figure. The 33 dB (RE) limit was obtained from the old 40 dB (RE) CCIF†† limit, which included 7 dB loss for the international section; 40 dB (RE) was, at that time, judged to be the limiting value of overall reference equivalent which could reasonably be tolerated on an international connexion.

* The designation (RE) is used in this article to denote decibels of reference equivalent. Reference equivalents (rather than loudness ratings) are used as they are still the current international standard.

†† CCIF—International Telephone Consultative Committee (the forerunner of the CCITT)



SRE_{MAX}: Maximum send reference equivalent (to the local exchange)
RRE_{MAX}: Maximum receive reference equivalent (to the local exchange)

FIG. 1—The existing UK transmission plan—nominal limiting connexion

In practice, even the 33 dB (RE) national limit was found to be subjectively unacceptable by the majority of customers[5]. Nevertheless, it was considered to be the best limiting connexion quality that could be afforded within the economic constraints that applied to analogue networks. Fortunately, this limit is rarely encountered as it requires a combination of all adverse links; an unlikely occurrence statistically.

THE IMPACT OF LOCAL NETWORKS ON PLANNING

In terms of transmission equipment, the local network, which includes customers' telephone instruments and lines to local exchanges, forms a major proportion of the national investment. In contrast to local cabling, long-distance transmission systems generally have a shorter working life and represent a smaller capital investment. Paradoxically, therefore, the very perimeter of the system (in network terms) tends to form the heart of the transmission plan, and the national and international connecting networks tend to be planned around it. It follows that digital penetration into the local network will, initially, be used only for growth (or to enhance the facilities offered) or for digital data connexions.

As the long-distance transmission and switching network approaches the all-digital state, the nominal loss of a connexion will be independent of its routeing. Hence, the national transmission planning strategy will be entirely dominated by the transmission parameters of telephone instruments, local lines and interface conditions at local exchanges. For this reason, it is necessary to anticipate the ultimate transmission aim of the network and to make plans for the change-over that ensure that no intermediate arrangement produces significantly worse performance than the existing analogue transmission plan—a commitment much easier to write than to carry out.

Ideally, it should be possible to allow complete interworking of digital and analogue networks. However, from an economic and practical viewpoint, it will almost always be necessary to restrict the range of possible routeings to limit the cost of the interworking systems and to preserve transmission planning standards.

THE AIM OF THE DIGITAL TRANSMISSION PLAN

The major factors which will influence the ultimate all-digital transmission plan are as follows:

(*a*) The primary network aim should be to ensure that all calls have a NORE that causes minimum customer dissatisfaction (approximately 4 18 dB (RE))[6].

(*b*) Adequate stability margins must be maintained on all classes of connexion; Datel services are likely to be the most critical in this respect.

(*c*) The echo performance must be satisfactory on all national classes of call without the use of echo suppressors/cancellors, which are costly items.

(*d*) The international recommendations[7] on stability and echo must be met (see CCITT† Recommendation G. 122).

(*e*) The traffic-weighted mean values of SRE and RRE specified in CCITT Recommendation G. 121[7] should be used as target values.

(*f*) The transmission plan should enable acceptable sidetone performance to be achieved.

By examining each of the above factors in turn it is possible to establish an overall view of what the new network transmission parameters should be.

Preferred Loudness Range

A statistical examination of UK local line reference equivalents (SRE and RRE) has revealed that a connexion with zero inter-exchange loss would result in calls being in a range approximately 6 dB louder than customers would prefer. Hence, the first requirement of a future digital network for inter-connecting existing local telephone circuits is the provision of a 2-wire to 2-wire loss on all classes of connexion of about 6 dB (this assumes that no change to existing telephone designs or line feeding arrangements occurs). This loss should be associated with the coder/decoder and not directly with the digital part of the transmission and switching system, thus ensuring that all classes of connexion encounter the same transmission loss. The principle of avoiding the use of digital-loss provision accords with the CCITT agreement that an evolving digital network should not be encumbered with equipment needed for the interim mixed analogue/digital era.

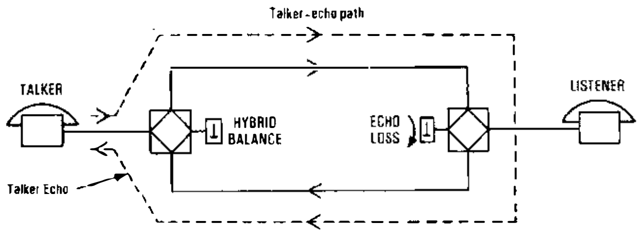
Stability Margins

A loop stability margin of 6 dB (as provided by the existing 3 dB loss pulse-code modulation (PCM) systems) has long been regarded as necessary and sufficient for Datel services in the UK. A feature of digital systems is that they provide effective 4-wire working (that is, independent GO and RETURN paths). Hence, if a 6 dB loss is provided for in a single 4-wire loop, a stability margin of 12 dB will be obtained on all call classes; this margin of stability is adequate for all likely requirements.

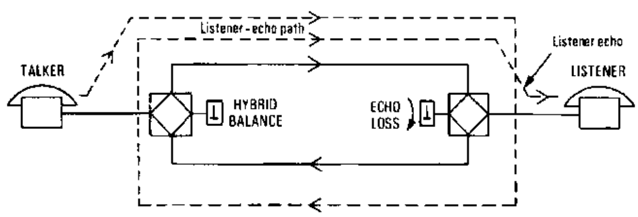
Echo Performance

Echo performance on present long-distance calls within the UK is largely satisfactory owing to the relatively high loss in the echo path contributed by the loss of the main transmission paths. As the transmission path losses will tend

† CCITT– International Telegraph and Telephone Consultative Committee



(*a*) Talker-echo path



(*b*) Listener-echo path

Note: For echo loss to be large, the balance network has to mirror the 2-wire impedance; 3-element networks will probably be needed to achieve the required degree of balance

FIG. 2—The main echo paths in a long-distance telephone conversation

to reduce in the digital era, care will need to be taken in the design of new local line interface units to ensure that the echo balance return loss is improved so that the overall echo-path loss is not reduced. To achieve the required echo balance return loss will probably require the use of 3-element balance networks at the 2-wire to 4-wire hybrids in a digital local switching unit (see Fig. 2).

Present-day 2-wire to 4-wire hybrid balances use 600 Ω resistive balances almost exclusively, but this choice is not ideal for interfacing with local lines, which are capacitive in nature.

International Recommendations on Stability and Echo

International recommendations require that national extensions contribute a minimum of 6 dB to the stability margin[8] of any international call when measured from the virtual analogue switching points (VASPs), (See Fig. 3). This stability margin is slightly lower than that given in the present CCITT Recommendation G.122[7] and stems from a recent decision made by CCITT Study Group XVI; the decision has not yet been ratified formally, but it is intended as a requirement for connexions established over a digital network.

One feature of a 6 dB loss 2-wire to 2-wire network is that it contributes a minimum of 6 dB stability loss between equi-level switchpoints (defined as the *a-t-b* loss in CCITT Recommendation G122[7]), as shown in Fig. 4.

The use of special hybrid balance networks for the control of echo on national calls will also provide for acceptable performance internationally. The CCITT Recommendation G.122[7] requires, at present, that the *a-t-b* echo path loss should have a mean value of not less than $(15 + n)$ dB with a standard deviation not greater than $\sqrt{(9 + 4n)}$ dB, where n is the number of 4-wire links in the national extension. Although the method of echo path measurement may change in the future, there is no reason to suppose that these values will be altered.

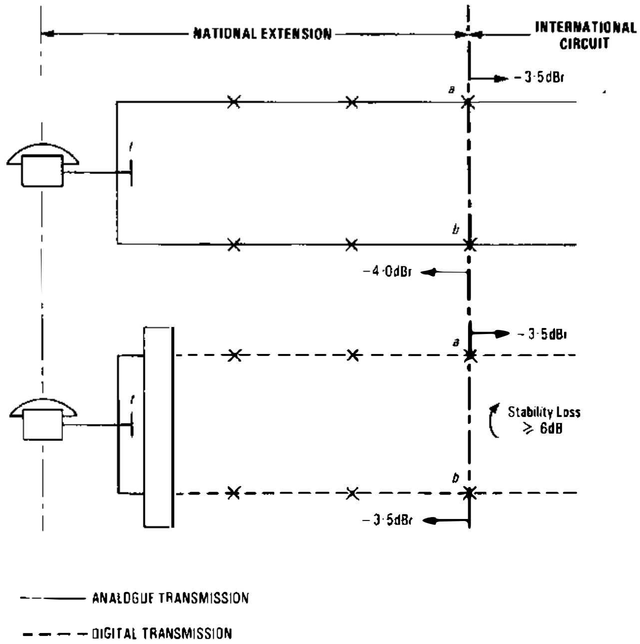
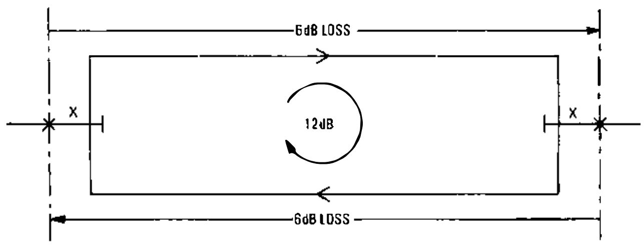
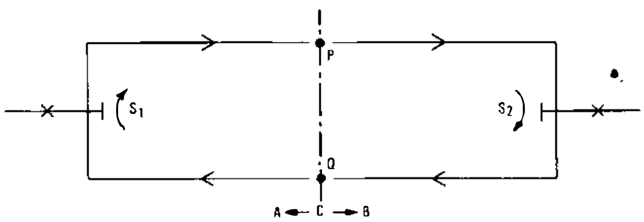


FIG. 3—Definition of virtual analogue switching points (*a* and *b*) in analogue and digital environments



Note: The stability margin of the above network is 12 dB with an open-circuit or short-circuit condition at points marked *X*

(*a*) 2-wire presented, 4-wire network of 6 dB loss



Note: A ≙ B; that is, surface C can be considered to be a mirror, and points P and Q are equi-level. Hence, stability loss S_1 equals stability loss S_2 and, because $S_1 + S_2 = 12$ dB, $S_1 = S_2 = 6$ dB.

(*b*) The network shown in Fig. 4(*a*) conceptually split in two identical halves—A and B

FIG. 4—The determination of the contribution to network stability of a 2-wire to 4-wire network

International Recommendations and their Effect on Telephone Instrument and Local Line Sensitivities

The CCITT recommendation G.121[7] gives guidance to national network designers on the long-term preferred range of traffic-weighted-mean (twm) values of SRE and RRE to the VASPs. The preferred ranges are:

(*a*) SRE_{twm}, 10–13 dB(RE), and
(*b*) RRE_{twm}, 2·5–4·5 dB(RE).

Summing the values of SRE and RRE would indicate a traffic-weighted-mean value of NORE in the range 12·5–17·5 dB(RE), which is not at the centre of the nominal minimum customer dissatisfaction range of 4–18 dB(RE). The implication appears to be that it is not possible to satisfy both criteria simultaneously. It should be noted that the CCITT preferred range takes note of the improved echo performance of higher loss connexions. However, bearing that in mind, provided that the echo performance does not suffer and due respect is paid to system loading and crosstalk criteria, there is no fundamental reason why values of SRE and RRE should not be chosen to minimize customer dissatisfaction. Median values of SRE and RRE to the VASPs of about 11 dB(RE) and 0 dB(RE) respectively have been chosen for the UK digital network. In practice, this is likely to yield a NORE range of about 6–20 dB(RE).

Sidetone Performance

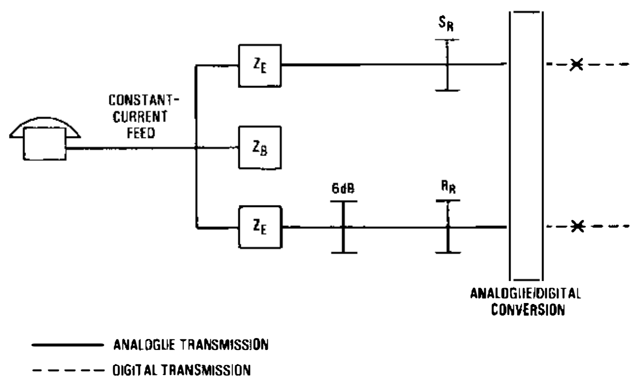
Sidetone performance has always been one of the weak points of the UK telephone network. The sidetone level returned to the earpiece has generally been considerably higher than in the networks of other countries; in particular, when compared with the sidetone presented to telephone customers in the North American continent. To some extent there is evidence that conditioning takes place and that users become accustomed to this phenomenon. Nevertheless, levels of sidetone corresponding to a sidetone reference equivalent louder than 10 dB(RE) (that is, less than 10 dB(RE)) produce an accompanying reduction of 1 dB in the mean speech power level for every 2–3 dB increase in sidetone level. This effect manifests itself as an effective reduction in the send sensitivity of the telephone. Careful consideration has therefore been given to improving this parameter.

The BPO 700-series telephones were designed to give their best sidetone performance when connected to a long length of 0·5 mm copper cable. Telephones on short local-lines give relatively poor sidetone performance and it is therefore considered desirable to mirror the characteristic impedance of 0·5 mm copper cable at the input of the customers' line interface units. In practice, however, it may be necessary to depart slightly from this value in order to cater for the requirements of Datel modems.

Telephone Line Feeding Arrangements

Present telephone line feeding arrangements use a constant voltage source to feed customers' lines and telephones. To reduce the problems caused by excessively loud calls, the over-loading of frequency-division multiplex equipment and crosstalk, all 700-series telephones use a regulator to reduce their send and receive sensitivity when the telephones are connected by short lines to the exchange. The regulator, which is activated by high line-feeding current (above 45–50 mA), achieves this reduction by shunting the AC speech path. However, an unfortunate side-effect exists in that the AC impedance of the telephone (as seen from the exchange) depends to a great extent on the value of the line feeding current. The contribution of the telephone to the impedance of the combination of local line and telephone as seen from the exchange is also most marked on short local lines. Therefore, owing to the combined variation of impedances of the telephone instruments and local lines, it is difficult, if not impossible, to choose a hybrid balance network which satisfies the requirements for echo and stability.

One way in which this problem can be overcome is to provide a low constant-current line feed (about 35 mA) from the exchange. This practice has the effect of fixing the impedance of the telephone in a condition that can be predicted, thus easing the choice of a balance network. The telephone instrument regulation function, which is rendered inoperable by this method, has to be transferred to the exchange. This can be achieved by sensing the voltage across the line current feed and setting the send and receive path attenuators accordingly (see Fig. 5).



Z_E: Exchange input impedance Z_B: Hybrid balance impedance
S_R: Send regulation function R_R: Receive regulation function
Note: For ease of description, the wanted transmission paths through the hybrid are shown as having zero loss and the 6 dB 2-wire to 2-wire loss is shown separately.

FIG. 5—Block diagram representation of the desirable digital local-exchange format (transmission parameters)

THE CO-EXISTENCE PROBLEMS

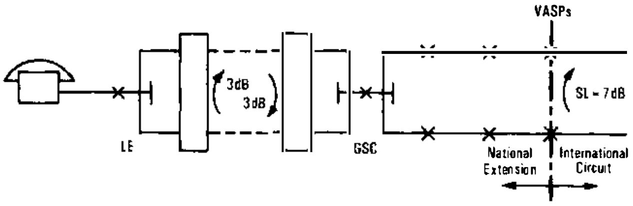
Deciding the preferred transmission attributes of a digital telephony network is essentially the easy part of the design exercise. As indicated previously, the problems raised in this era of rapid change, caused primarily by interworking difficulties, are somewhat more onerous to solve. Essentially, the difficulty arises from the need to ensure that the new network can interwork with the old (providing a performance that is at least as good as, and preferably better than, the performance of the existing network) while, at the same time, choosing transmission parameters that will satisfy the preferred aims of the digital era. This juggling exercise is complicated by the necessity to safeguard the service to such diverse areas as private leased circuits, operator services, Datel, PABXs and emergency services, all at the same time. Some of the problems can be resolved using basic transmission techniques, others require routeing restrictions or special provision. Care was exercised in the initial statement of the digital network aim so that these difficulties were minimized, bearing in mind the fundamental ideology that, wherever possible, the shortcomings of the existing network should not be allowed to influence the final digital plan adversely. This iterative planning process has largely been completed.

Although it is not possible to cover each of the problems in detail, a selection of the more important ones has been included so that their general nature can be more readily understood.

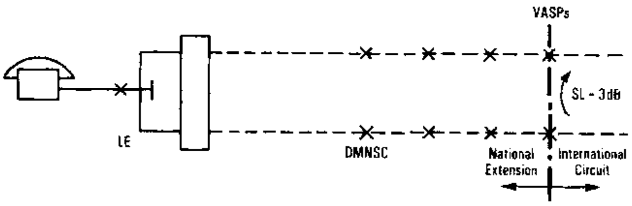
PCM Equipment and the 6 dB Network Loss Requirement

Present PCM junction systems are designed to have a nominal 2-wire to 2-wire loss of 3 dB. If such systems were used without modification as the basic building block of a new digital network it is apparent that the UK national 4-wire network would eventually reach a 3 dB loss condition. If this were to be the case, then the BPO could not honour its international obligations regarding stability margins without the use of digital loss. Fig. 6 illustrates the progression of events which would occur naturally from the use of PCM circuits having a 3 dB nominal loss.

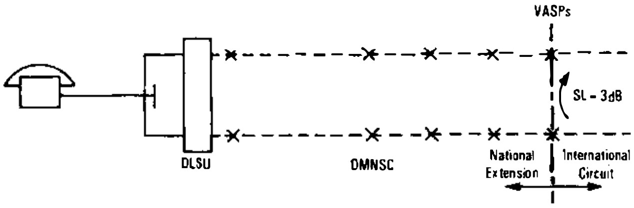
Because this situation is unacceptable from a stability loss standpoint, it was necessary for the BPO to make provision for



(*a*) International connexion (via transit network) including part digital transmission (PCM junction)



(*b*) International connexion using digital transmission to analogue local exchange



(*c*) International connexion using digital transmission to a DLSU

——— ANALOGUE TRANSMISSION
– – – – DIGITAL TRANSMISSION

SL: The stability loss exhibited by the national extension
LE: Analogue local exchange
GSC: Analogue group switching centre
DLSU: Digital local switching unit
DMNSC: Digital main-network switching centre
VASP: Virtual analogue switching point

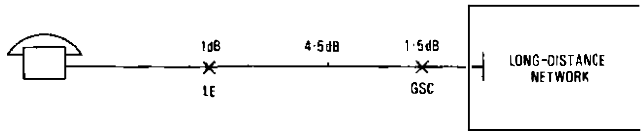
FIG. 6—International incompatibility of 3 dB loss national network

the change-over to a 6 dB national network. Second generation PCM systems and digital local switching units (DLSUs) will have provision to enable them to be changed from 3 dB to 6 dB loss without the need for digital recoding.

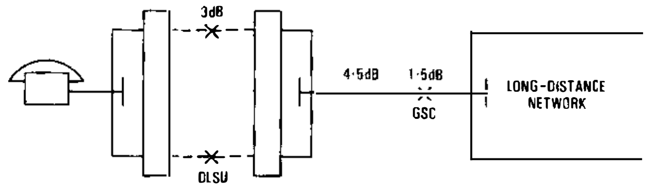
Isolated Digital Local Switching Units

When a DLSU is provided as a replacement for an analogue local exchange, extra connexion path losses will be incurred. The reasons for this extra loss can be seen from Fig. 7, which is annotated with nominal limiting losses. In principle, an extra 4 dB could be added to the loss of a national call (2 dB at each end). This situation militates against the fundamental principle of avoiding worsening customer service and is therefore unacceptable.

Before considering more expensive solutions to this problem, the possibility of incorporating extra gain in the 4-wire path was considered, thus capitalizing on the return loss available from a permanently-associated junction. However, it soon became clear that this was no answer to the problem. Experience had shown that the effective loss of such arrangements had to be systematically increased, with the result that all junction circuits, regardless of length, would introduce the maximum permitted loss (or even more). This loss arises from the need to maintain a 6 dB stability margin. Fig. 8 illustrates the quantities involved. Furthermore, there are additional practical difficulties associated with this solution because

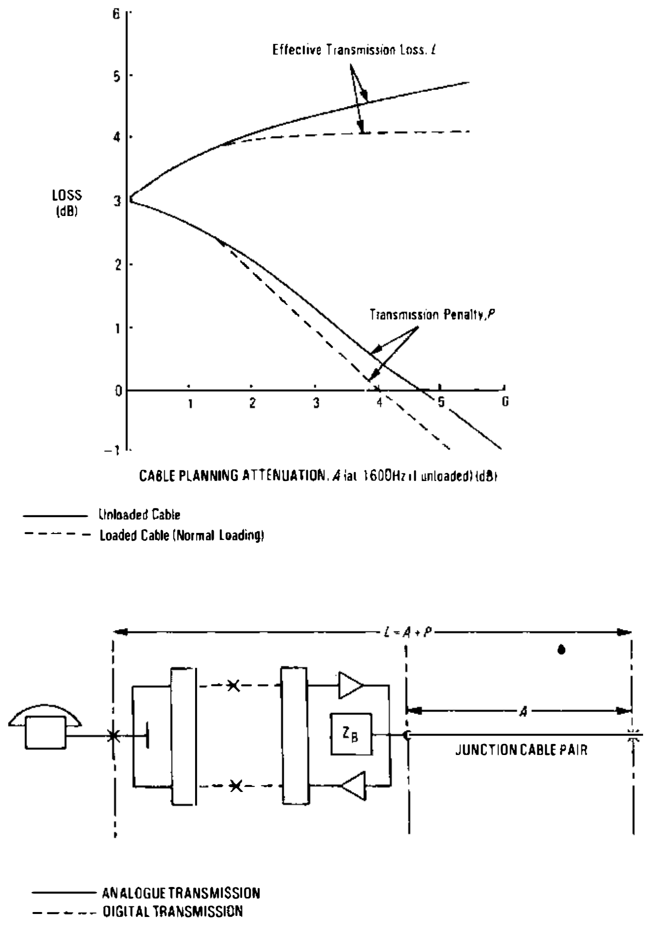


(*a*) Existing analogue situation



(*b*) Isolated digital local switching unit

FIG. 7—The incorporation of an isolated digital local switching unit in the network



Notes: (*a*) The value of *L* is chosen such that the stability margin of the complete exchange and junction unit is not less than 6 dB
(*b*) Z_B is a special hybrid-balance network
(*c*) The DLSU is shown with analogue concentration

FIG. 8—Transmission penalty associated with 4-wire switched, 2-wire junctions

(*a*) all loaded junctions must be correctly built-out (that is, the cable ends must each appear as a half loading-coil),

(*b*) there is no simple solution for mixed junctions,

(*c*) the implementation of this technique requires the use of large and expensive balancing networks whose construction is not reasonably compatible with digital switching practice, and

(*d*) the reliability and maintenance problems of such a solution are also in doubt.

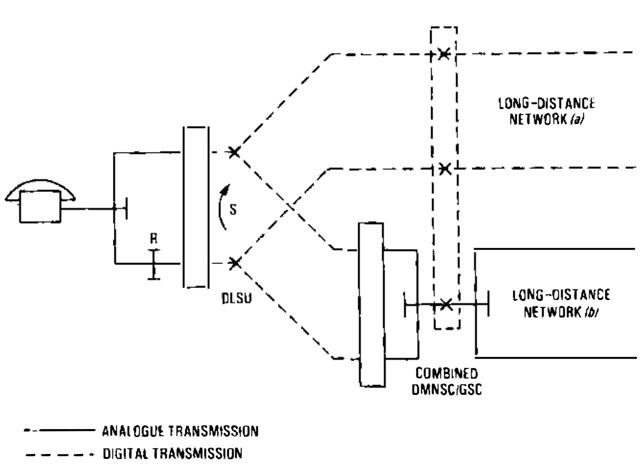
Consequently, the decision was taken to make provision for 4-wire trunk junctions to interconnect each DLSU to its main switching unit (MSU). The need to implement this rule exists regardless of whether the MSU is an analogue GSC or a digital main network switching centre (DMNSC).

Problems of Implementing a 6 dB Network Loss

In practice, the change from analogue to digital working cannot be achieved overnight. This too is the likely situation for MSUs; for example, digital extensions will probably be added to existing GSCs. The means of increasing the network loss from 3 dB to 6 dB must be located on the analogue side of the local line interface unit at the DLSU if digital loss is to be avoided (the use of digital loss provision involves digital recoding and therefore militates against the use of a multi-purpose digital network). Because the DLSU will be connected to both parts (analogue and digital) of the MSU, it is not possible to choose readily the correct value of network loss. If 6 dB loss is chosen on the grounds advanced earlier in this article, then the present transmission standard will be exceeded on certain national calls; for example, calls routed via a GSC. Conversely, the 3 dB loss will break the international agreement on stability if this path is routed via the DMNSC and the routeing is digital throughout. The solution is patently not simple, the problem being illustrated by Fig. 9.

For this mixed MSU situation, the BPO has decided that originating traffic from a DLSU shall always be routed via its DMNSC, and extra trunk routes will be provided to meet this need. However, it is not possible to guarantee that incoming traffic will always be routed via the DMNSC unless all MSU terminating traffic is routed via the DMNSC. This implies that the DMNSC extension would have to possess a much larger traffic-handling capacity than would otherwise be necessary, which would incur an economic penalty.

The solution that has been agreed is somewhat complicated and is, of necessity, a compromise on all sides. The present minimum *a-t-b* loss of 7 dB will be preserved initially by routeing international calls via the analogue network because, for national purposes, a 4 dB analogue interfacing loss is applied between the analogue and the digital networks. However, national calls over fully digital plant will have to endure a nominal 3 dB network loss initially. This loss will



Notes: For connexions via path (*a*), S ≥ 6 dB; hence, R_{MIN} = 6 dB
For connexions via path (*b*), S = 3 dB; hence, R_{MAX} = 3 dB

FIG. 9—The implementation problem of the 6 dB loss requirement

result in a poorer echo performance than is desirable; the most critical case in this respect is the fully digital (transmission and switching) connexion. This type of connexion combines the low loss with a significant propagation delay; to reduce the risk of impaired connexion performance due to echo, not more than 3 MSU to MSU digital routes will be used in tandem. This routeing restriction will not entirely protect national calls against echo, but it will prevent impairment due to echo from reaching unreasonable proportions in the interim period.

The next important milestone in the realization of a wholly digital network will be the introduction of a digital international switching centre (DISC). All digital routeings from a DLSU to a DISC will need to be operated at the 6 dB standard. Thus, it will be necessary to ensure that any DLSUs so connected have full access to the national digital network both for originating and terminating calls, even if part of the MSU is still an analogue GSC. The same rule will apply to an analogue local exchange fed with digitally integrated PCM systems from the DMNSC. Careful network planning will therefore be needed over the coming years to ensure that this situation is reached in time for the introduction of DISCs. Furthermore, in order to avoid a work peak that would be necessary using overnight change-over procedures, care will need to be taken to ensure that the network progresses gradually towards this mode of operation, while minimizing the extra cost of digital trunk provision.

One final problem still exists even if all present network proposals are implemented without undue difficulty. Local connexions set up by direct junctions or via tandem exchanges will exhibit greater loss than at present. Fortunately, the situation is not as bad as it might at first seem because

(*a*) these connexions exhibit relatively low losses at present,

(*b*) it may not be too difficult to reduce the loss of the junctions, thus partially offsetting the extra loss in the DLSU, and

(*c*) the need for direct junction routes is likely to reduce considerably with change to the economics of provision for extra digital circuits for tandem traffic via the MSU.

DMNSCs and Existing Automanual Centres

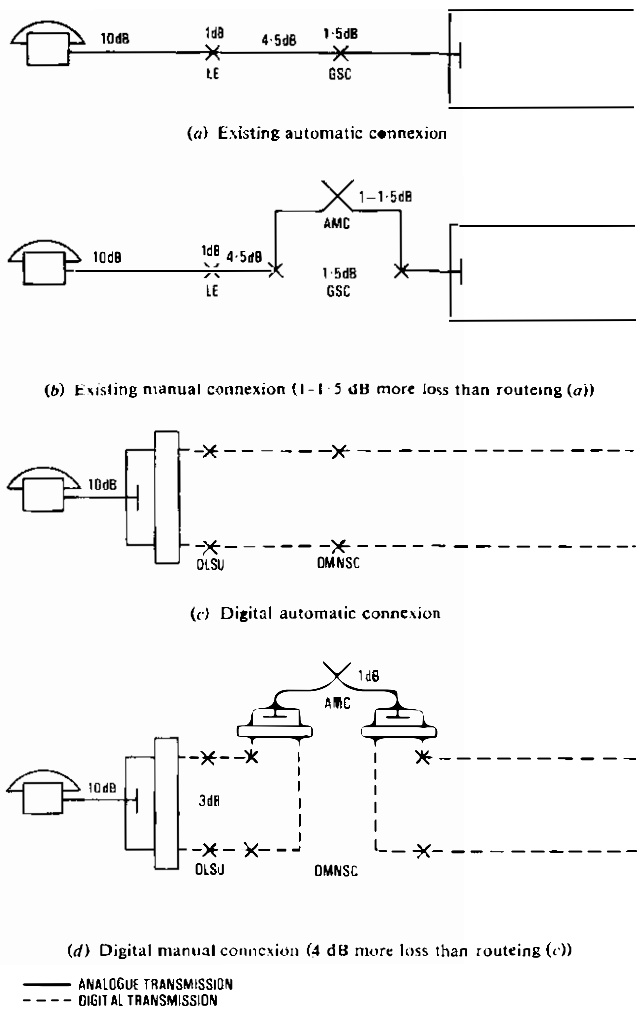
Under the existing transmission plans, no allowance was made specifically for the extra loss incurred on calls via an automanual centre (AMC). An extra loss of perhaps 1·0–1·5 dB over and above the equivalent automatic connexion might normally be expected. However, with the introduction of a fully digital MSU, the *relative* situation is worsened significantly. The fundamentals of the problem, with nominal maximum losses annotated, are illustrated in Fig. 10.

No obvious solution to the problem exists at this stage but, in the long-term, it is hoped that effective 4-wire transmission facilities will be available at the AMC, thus incurring no extra loss in this condition. However, network considerations may demand that AMC traffic is not doubly switched at the MSU and, in certain circumstances, separate routes to the AMC may become a permanent feature of the network.

Small analogue local exchanges parented on DMNSCs present problems of their own because it is not practical to separate their level-1, level-9 and level-0 traffic. Special arrangements need to be made in these circumstances to extract the AMC traffic before it enters the switch.

Private Branch Exchanges in the Digital Network

Private branch exchanges (PBXs) have long been a problem to the network planners. Mainly due to such factors as long external extensions, inter-PBX tie-lines and mixtures of 2-wire and 4-wire switching, the present limiting connexion condition is often approached and even exceeded in severe cases. Ideally, those PBXs connected to DLSUs should use 4-wire



(a) Existing automatic connexion

(b) Existing manual connexion (1–1·5 dB more loss than routeing (a))

(c) Digital automatic connexion

(d) Digital manual connexion (4 dB more loss than routeing (c))

FIG. 10—Extra loss associated with 2-wire automanual centres.

local line transmission (that is, the 4-wire to 2-wire interface is moved from the DLSU to the PBX). If this was so, the local line loss could be completely eliminated (digital connexion) or at least substantially reduced (4-wire analogue transmission). This ideal solution is applicable both to analogue and digital PBXs.

Digital PBXs interconnecting 2-wire presented circuits raise special problems of their own which arise from similar considerations to those applicable to the DLSU. Again it is important that adequate stability margins are preserved and this implies a minimum 2-wire to 2-wire loss of 3 dB for the PBX. However, in certain circumstances, usually on long uniform exchange-lines, it is possible to reduce the loss on extension to exchange calls. Unfortunately, where the PBX is also used for switching tandem traffic (via inter-PBX tie-lines), the situation is somewhat different and network stability may need to be preserved by means of the switching of analogue attenuators.

There is now a considerable demand from private companies for the introduction of digital PBXs; in particular, from the users of private leased networks who are often attracted by the facilities of digital PBXs. The transmission position is not necessarily quite so attractive and, where analogue 2-wire switched exchanges are to be replaced by 3 dB loss digital units, extra network loss will be encountered.

Remedial action could involve

(a) the reduction of the 2-wire to 2-wire loss of the digital PBXs from 3 dB to about 1 dB, or

(b) the alteration of the interface between the digital PBX and transmission line to 4-wire working, thus enabling the end-to-end connexion loss to be reduced.

Course (a), which is attractive from a simple drop-in replacement point of view, is unacceptable owing to the considerable interaction of the number of low-loss high-delay, 4-wire transmission loops connected in tandem. The position that it would create is somewhat analogous to that in the day of the "best possible" trunk circuits, which were associated with stability problems and difficulty of operating Datel services, not to mention the unpleasant subjective effects on telephony; for example, the hollowness of received speech. It is therefore important that all digital PBXs are provided with 4-wire interface facilities, preferably digital and conforming to CCITT Recommendation G.712[7].

Some Examples of Nominal Overall Reference Equivalents.

So far, this article has dealt only with the strategy required to overcome the problems which will be encountered during the period of change from an analogue to an all digital network. The results anticipated from the proposed solutions for some connexion configurations are given in Table 1; it must be stressed that the information given in Table 1 relates to the effect on nominal overall reference equivalents only, it does not relate directly to customers' subjective opinions of performance. In the case of PBX connexions, the values of NORE given in Table 1 are approximate owing to the variety of circuit configurations that can exist.

TABLE 1

Nominal Overall Reference Equivalents for given Connexion Routeings

	Type of Connexion	Maximum Value of NORE (dB(RE))
1	Analogue long-distance circuit, 2-wire switched (at GSC) to digital route (see circuit routeing (b) of Fig. 9 with R = 6 dB)	34·0
2	Connexion routed automatically in accordance with existing transmission plan (see Figs. 1 and 10(a))	32·5
3	Connexion routed via automanual centre (existing arrangement—see Fig. 10(b))	34·0
4	Connexion to trunk network via DLSU and DMNSC (see Fig. 10(c))	29·5
5	As (4) above, but with manual facility (see Fig. 10(d))	33·5
6	PBX-PBX call routed via the public switched telephone network and involving an inter-PBX tie-line with an external extension at the distant end	≃44·0
7	As (6) above, except that the PBX is connected to a DLSU at the originating end (4-wire transmission PBX to DLSU)	≃40·0
8	As (6) above, except that the originating and distant PBXs are connected to a DLSU (4-wire transmission, PBX to DLSU) and the tie-line is 4-wire	≃30·0

CONCLUSION

At this time, the precise form of the ultimate UK digital transmission plan is not known. However, it seems inevitable that 4-wire switching and transmission will gradually overtake their present 2-wire equivalents and that, because of the economic advantages obtained from common traffic routeings, a switching hierarchy will remain.

From a transmission standards viewpoint, there is no single reason why, at the lower stages of this hierarchy, there should not, eventually, be more switching units in a connexion path than allowed at present (3 GSCs in tandem); cumulative propagation delay and echo are factors of prime importance in this matter. Meanwhile, it is important that careful consideration is given to every decision affecting transmission standards so that the dual objectives of not worsening the existing customers' services or deviating from the aim of providing a network with optimum performance is achieved.

It would be excusable if the reader had by now concluded that digital transmission and switching creates more problems than it solves. However, the eventual advantages that will accrue from full digital working in terms of transmission quality, flexibility and cost must be borne in mind. Telephone network design is vastly different from what it was a decade ago. More than ever before it is necessary for the experts in transmission, switching, signalling and routeing to work closely together, and for each to have a considerable appreciation of the others' problems. Moreover, the use of digital switching and transmission methods will bring the national and international network problems right into the local network. Consequently, a local switching unit designer must have a complete grasp of all the standards which influence network performance. It is indeed fortunate that computers, which are revolutionizing the design of switching systems, are also available to provide the means of facilitating many of the design procedures which would otherwise prove virtually impossible to achieve.

References

1 HARRIS, L. R. F., and DAVIS, E. System X and the Evolving UK Network. *POEEJ*, Vol. 72, p. 2, Apr. 1979.

2 TOBIN, W. J. E., and STRATTON, J. A New Switching and Transmission Plan for the Inland Trunk Network. *POEEJ*, Vol. 53, p. 75, July 1960.

3 BOAG, J. F., and SEWTER, J. B. The Design and Planning of the Main Transmission Network. *POEEJ*, Vol. 64, p. 16, Apr. 1971.

4 ELLIOTT, J. L. C. The Design and Planning of the Junction Network. *POEEJ*, Vol. 65, p. 12, Apr. 1972.

5 FRY, R. A., and BANNER, I. H. Transmission Performance Assessments of Telephone Networks. *POEEJ*, Vol. 65, p. 145, Oct. 1972.

6 RICHARDS, D. L. Telecommunication by Speech. Butterworth, p. 280.

7 CCITT Orange Book Vol. III. International Telecommunications Union.

8 MUNDAY, S., and FRY, R. A. The New International Telephone Switching and Transmission Plan. *POEEJ*, Vol. 61, p. 199, Oct. 1968.

Forthcoming Conferences

Further details can be obtained from the conference department of the organizing body.

Institution of Electrical Engineers, Savoy Place, London WC2R 0BL. Telephone: 01-240 1871

Transmission for Telecommunications Purposes

7–12 September 1980
Vacation school at University of Aston

Stored-Program Control of Telephone Switching Systems

7–12 September 1980
Vacation school at University of Essex

Switching and Signalling in Telecommunications Networks

14–19 September 1980
Vacation school at University of Aston

Optical Communication

16–18 September 1980
University of York

The Impact of New LSI Techniques on Communication Systems

1–2 October 1980
Institution of Electrical Engineers

TXE4A (co-sponsored by IPOEE)

28 October 1980 (evening meeting)
Institution of Electrical Engineers

International Telecommunications Energy Conference

19–21 May 1981
Royal Lancaster Hotel, London

Institute of Physics, 47 Belgrave Square, London SW1X 8QX. Telephone: 01-388 3071.

Physics of Dielectric Solids

8–11 September 1980
University of Kent

European Solid-State Device Research Conference

15–19 September 1980
University of York

MEPL Ltd., Temple House, 36 High Street, Sevenoaks, Kent TN13 1JG. Telephone: (0732) 59533

Microwave

8–12 September 1980
Warsaw

Small Exchange Modernization: New Electronic Exchange Systems UXE7 and UXE8

A. E. POULTNEY, B.SC., and J. C. LASHMAR, M.I.T.E.†

UDC 621.395.45: 621.395.722

The British Post Office has so far given a lower priority in its modernization plans to the replacement of small step-by-step exchanges of less than 600 lines, although, in the longer term, appropriate digital exchanges of the System X family will undoubtedly be developed. This article outlines the background to an interim phase, resulting in the decision to purchase two new small proprietary systems, and describes the equipment practice and manner of operation of each system.

INTRODUCTION

The policy of the British Post Office (BPO) is to modernize all its medium/large local exchanges by 1992. To this end, much progress has already been made with TXK1, TXK3 and TXE2 exchanges, and is currently being made with TXE4 and TXE4A exchanges. In the near future, the first System X exchanges will appear in the network, and thereby will enable the initial modernization task to be completed.

Many small exchanges of more than 600 lines are being replaced with TXE2 exchanges; however, the BPO modernization policy for exchanges below 600 lines is to await a System X variant that will provide the appropriate solution in terms of timescale, technology, facilities and overall system compatibility. Although very small exchanges constitute a significant proportion (approximately 35%) of the total number of BPO exchanges, a delayed start to the programme of modernization will not place a major burden on the BPO's labour resources in most of the UK.

However, in two Areas of the Scottish Telecommunications Board (STB), where very small exchanges predominate, the modernization programme is likely to place a significant strain on the labour force, and delaying the start will serve only to exacerbate the problem. Details of the number of exchanges in the two Areas are given in Table 1.

It has therefore been decided to purchase a limited number of two proprietary small exchanges, designated UXE7 and UXE8, to be installed exclusively in two Areas of the STB. The systems haveeach been developed by UK telecommunications equipment manufacturers (GEC Ltd. and Plessey Ltd.), primarily for the export market. This purchase will enable the STB to make an early start with small exchange modernization; at the same time, it will enable the BPO to develop new maintenance procedures and techniques for small exchanges, and to evaluate the systems to determine if they have any place in the overall modernization strategy. The STB has the major responsibility for planning, installation and maintenance, and has been working very closely with both manufacturers throughout the project.

† Exchange Systems Department, Telecommunications Headquarters

TABLE 1
Number of Exchanges Classified by Size

Area	Exchange Type	Number of Exchanges having Connexions of:				Totals
		0–100	101–200	201–300	301–400	
Aberdeen	UAX 12	100	13	—	—	113
	UAX 13	76	42	22	19	159
	SAX	8	51	9	4	72
Scotland-West	UAX 12	76	7	—	—	83
	UAX 13	36	19	11	15	81
	SAX	11	37	11	4	63
	Totals	307	169	53	42	571

STRATEGY

To avoid an early clash with the System X implementation programme, the exchanges are being installed in two lots of 12, grouped around 4 TXK1 GSCs. The sites have been chosen as far as possible to facilitate installation, maintenance and training, and use is being made of the existing buildings—generally a BI type; existing junction arrangements are being used in most cases.

The exchanges will be fully assembled, commissioned and accepted in the factory under BPO supervision, and then dismantled and delivered to site. Installation and on-site testing will be carried out by BPO staff. Plug-and-socket cabling is used extensively in both systems.

One exchange of each type is being provided with MF4 signalling capability to assess customer response in the rural areas of Scotland.

DESCRIPTION OF SYSTEMS

Both systems have some affinity to TXE2[1,2] in that they are both space-switched systems designed for unattended operation and use reed relays for switching the speech path. An outline description of each system follows.

THE UXE7 SYSTEM

The UXE7 system is manufactured by GEC Ltd. and has the proprietary designation *RS22*. A containerized version has been used as part of an export demonstration for GEC at Clipston Exchange in the Leicester Telephone Area. The RS22, which replaced an existing UAX13 on a temporary basis, has now been in satisfactory operation since January 1978. The UAX13 has been kept on stand-by in case a change-over becomes necessary, but this has not occurred to date. The excellent reliability of the RS22 has given a good deal of reassurance to the STB that this exchange system will prove ideal for the remote locations chosen for the UXE7.

General

The UXE7 uses T10000 equipment practice and is manufactured in two rack heights: 2·0 m and 2·6 m. The 2·0 m high equipment is intended primarily for containerized use or for low-ceiling-height buildings, but can be the most economical version for exchanges with very low connexion capacity. For the evaluation exercise, the BPO is purchasing equipment of both rack heights, the 2·0 m high equipment being used in exchanges of up to 200 connexions. The maximum size of the UXE7 in either rack height is 1000 connexions.

The control portion of the exchange is duplicated for security, and the exchange has remote and/or local fault print-out. Several of the logic functions are self checking and, in the event of a fault, can initiate change-over to duplicated equipment, followed by an automatic second attempt.

To give the maximum reliability and the minimum of maintenance needed for use in remote locations, the UXE7 has been designed to use no open contact devices such as 3000-type relays. The coin-and-fee-check (CFC) unit has been replaced with a solid-state/reed-relay design and, for the signalling elements for DC2, CFC coin-pulse signalling etc., electronic solutions have been used in place of traditional Carpenter or other specialized relays.

Principal Equipment Items

The UXE7 system has three main equipment areas:

(*a*) The equipment which is involved in switching the metallic pair through the exchange, comprising the line circuit, A-switch, B-switch and supervisory circuits.

(*b*) The equipment which controls the functions of the items in (*a*) and which is held for only a short duration during the setting-up of a call; namely, the minicoder, Q stores and control, marker control, and translator. These items are collectively known as *call control*.

(*c*) Registers, which are used to store and forward information as appropriate.

Each of these items is briefly described below, and their interconnexion is shown in the outline block diagram of the exchange given in Fig. 1.

Line Circuit and Switches

Each A-switch comprises a 5 × 5 reed-relay matrix, providing access to five subscriber's line circuits. The outlets are connected to a series of B-switches, each consisting of a 5 × 15 reed-relay matrix. The B-switches are arranged to provide full-availability access to supervisory units for exchanges of up to 500 connexions, but may give limited-availability access on the larger sizes. (Note that the B-switch is the same unit as used in GEC-manufactured TXE2 C-switches.)

Supervisory Units

All supervisory units use reed-relay control of the line pair and have electronic timing/metering modules.

Minicoder

The minicoder is a fixed-field dimond-ring coder, containing 16 duplicated cores. Each subscriber and incoming or both-way supervisory unit, has a threading such that, when a current pulse is initiated by the line circuit or supervisory unit, the sense amplifier generates the calling-line identity. A minicoder can handle a maximum of 500 subscribers and 48 incoming or bothway junctions. A second minicoder, with threadings coded differently, is used for exchanges exceeding these parameters; this gives a total capacity of 1000 lines and 96 incoming or bothway junctions.

Q Stores and Control

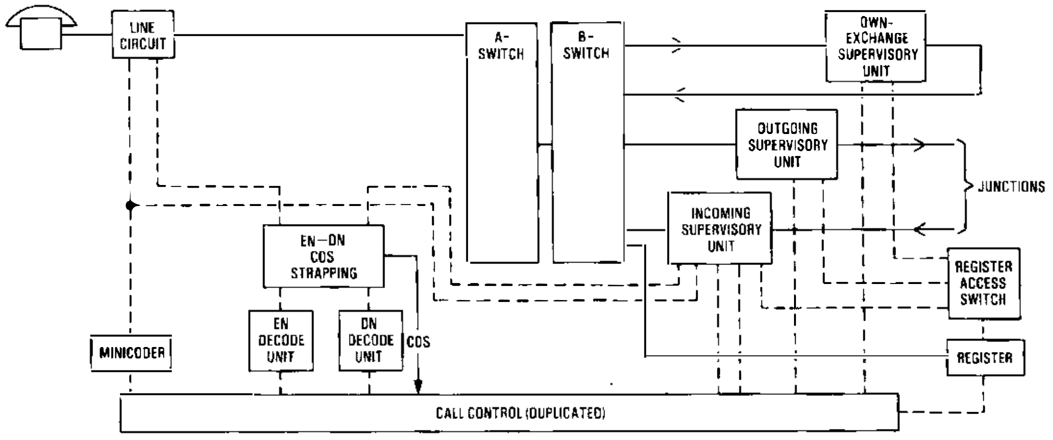
The coder control has two Q stores, which provide a buffer store between the minicoder and the translator. Buffer storage is necessary because the minicoder requires immediate attention, whereas the translator must complete the job in hand before dealing with a new call. If either of the Q stores contains an incoming-junction identity, this is given priority over originating calls to facilitate the association of a register prior to receipt of incoming-junction signalling information. If a coder control cannot obtain service within 100 ms, it initiates a security change-over and attempts to progress the call on the other security side.

Marker Control

The marker control is the interface between the translator and registers, and controls the switchblock. The logic is mainly solid state, but uses mercury-wetted reed relays for the most arduous tasks. The marker control also provides the signal-conversion circuits between the −50 V and −5 V logic.

Translator

All calls, whether they are originating or incoming, make an application to the translator via the minicoder and Q-store control. The primary function of the translator, upon receipt of a Q-store demand, is to connect the subscriber or incoming junction to a free register, which will receive the signalling information. Subsequently, the register makes applications to the translator after receipt of each digit; this continues until enough digits have been received to enable the translator



EN—Equipment number
DN—Directory number
COS—Class of service

FIG. 1—Functional block diagram of the UXE7 system

to generate the routing information and sending programme, and to recognize end-of-dialling or barring where applicable.

All information sent to the register is repeated back to the translator, which then compares the sent and received signals. If transmission is unsatisfactory, the exchange changes over to duplicated equipment and makes a second attempt to complete the call.

Register

The UXE7 uses one type of register, which handles all classes of traffic. It has storage for up to 20 digits and this adequately meets the needs of international calls. The register repeats all necessary digits and, hence, fully controls the digits sent to line. It is not possible for a subscriber to dial through the supervisory units.

After receipt of each digit, the register applies to the translator for all digit decode and inspection functions, thus eliminating the need for strapping decodes within the registers. Connexion to the supervisory unit is via a 6-wire reed-relay access switch. The register uses primarily transistor-transistor logic, but reed relays are used to connect the originating and terminating line pairs. Dial tone is returned from the register. On all calls terminating on UXE7 and UXE8 exchanges, called subscribers are given first-burst ring and calling subscribers are given first-burst ring tone†; both functions and their timing are controlled and supplied by the register.

The register can send up to 20 digits, either as received, or with up to six translated digits; a comprehensive range of inter-digital pauses and ambiguity options are available for dealing with mixed number lengths in local, national and international routings. However, ambiguity in the end-of-dialling point does not increase the post sending delay as the register completes a temporary transmission path internally during the 4 s time-out period*. If the called party answers during the time-out period, a line reversal received on the outgoing pair of the register overides the time-out condition and signals to the supervisory unit to take over the call immediately. As a by-product, the same register line-reversal detector is used to detect premature signals that may occur before the earliest possible end-of-dialling point is reached. Detecting that the call cannot mature, the register releases the forward connexion and returns congestion tone to the calling subscriber.

System Operation

Call Origination

When a subscriber originates a call, the associated line circuit generates a one-shot pulse in the minicoder (Fig. 1); this assigns the line-circuit equipment number (EN) to a Q store to await the attention of call control. On receipt of a demand from the Q store, call control selects a free register and receives the calling-subscriber's EN. The EN is then decoded in the EN decode unit and the subscriber's marker relay operated via the main strapping/core field; this also generates the COS, which is passed to the call control. Receipt of the COS enables the call control to determine whether any additional equipment (for example, coin-collecting-box (CCB) control, multi-frequency (MF) Keyphone receiver) or specialized operation of the register such as shared-service interrogate is required.

Call control then switches the calling line, via the A- and B-switches, through to the selected free register and, concurrently, forwards the calling-subscriber's identity, COS, state of call etc. serially to the register. The register makes this information available to the translator on all subsequent recalls.

At this stage the register returns dial tone and awaits the first dialled digits from the calling subscriber. The registers have minimal wired intelligence and contain no digit decode facilities. Hence, on receipt of the first and each subsequent digit, the register gains access to call control for digit inspection; call control inspects the received digits and the subscriber's COS to see if routing is possible and permitted.

As soon as enough digits have been received to determine the required route, call control selects a free supervisory unit of the type required and establishes a new path from the calling line, via the A- and B-switches, to the selected supervisory unit and also a new path through the register access switch to connect the supervisory unit to the register associated with the call. On completion of these new paths, the register is instructed to release its own path through to the calling line. This make-before-break approach is essential to avoid loss of originating information from push-button telephones using MF4 signalling.

Own-Exchange Call

As soon as sufficient digits have been received to allow call control to identify an own-exchange call, an own-exchange supervisory unit is associated (see Fig. 2). When sufficient digits have been received, call control checks that the called line is free and that its COS allows the receipt of the call. If both of these conditions are satisfied, call control sets up a path, via the A- and B-switches, from the own-exchange supervisory unit to the called subscriber. The register is then instructed to go into a terminating-call clear-down procedure, which involves the sending of first burst ring signals and then releasing, leaving the own-exchange supervisory unit to provide the necessary supervisory functions for the duration of the call.

Outgoing Call

The call origination is as previously described, except that an outgoing supervisory unit is selected; call control then updates the register stores, which instruct the register of the required sending programme. The register sends all the required digits, instructs the outgoing supervisory unit to switch the transmission path, and then releases from the call. If necessary, the translator can determine the required route and call control can carry out the supervisory unit selection process. This enables the register to commence sending digits before sufficient digits have been received to determine the end-of-dialling point, or late barring etc.; this avoids incurring unnecessary post-dialling delays.

Incoming Call

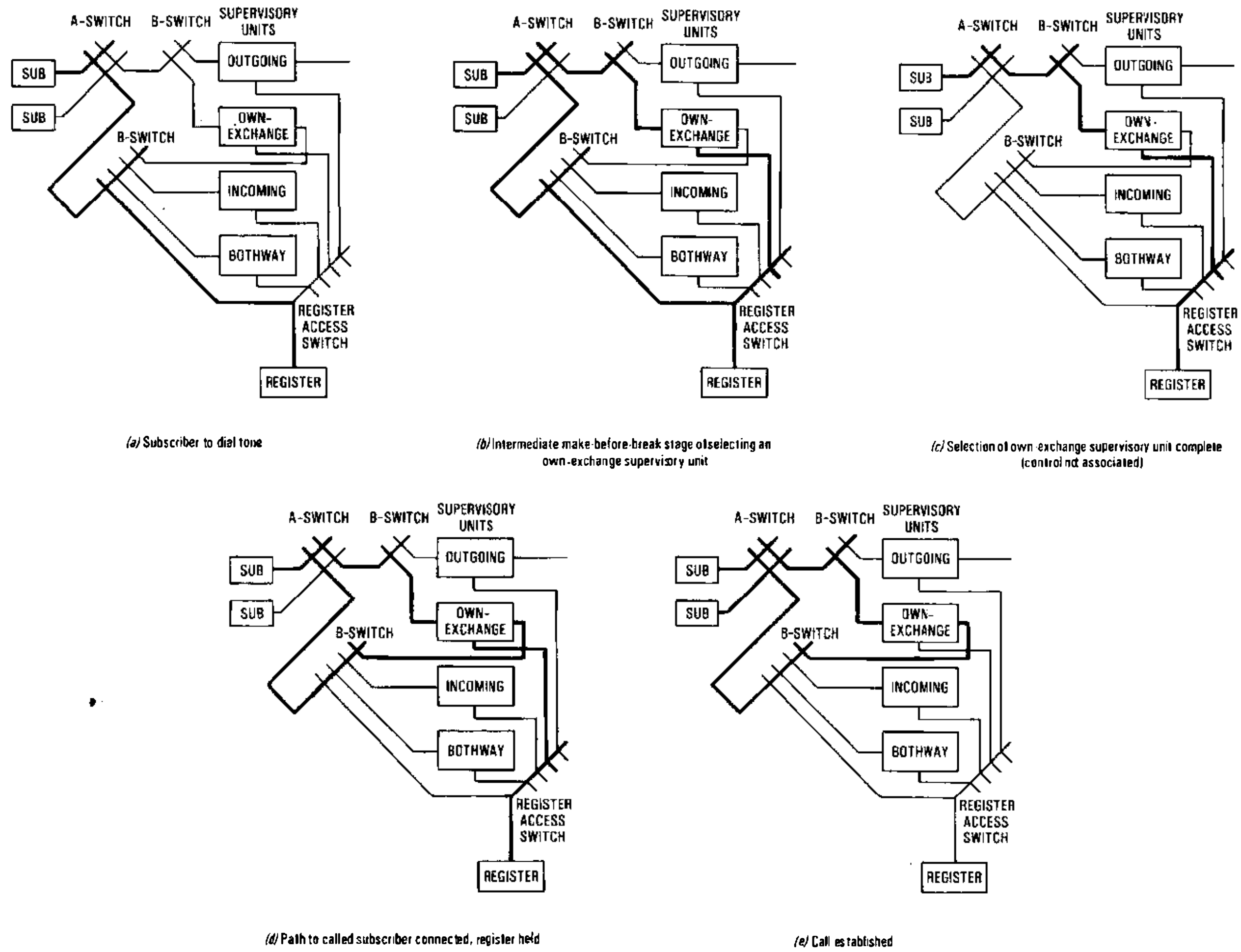
An incoming call via an incoming or bothway supervisory unit generates a one-shot pulse to the minicoder on seizure. The identity of the supervisory unit is stored in a Q store and given priority by call control over all other calls in the queue. The EN stored in the Q store enables call control to identify and establish a connexion to the incoming supervisory unit, and allows a path to be established through the register access switch to a free register. The register then awaits the incoming information and deals with it in a similar manner to an own-exchange call.

THE UXE8 SYSTEM

The UXE8 system is derived from one of Plessey's Pentex range which, for export, is designated *ERS* (Electronic, Reed, Small). Modification has been necessary to conform to the BPO CFC and local call timing (LCT) arrangements, and to align with normal UAX12/13 combined 1/9/0 junction arrangements. Another member of the Pentex range has previously been described in this *Journal*[3].

† First-burst ring and ring tone are always connected to the called and calling subscribers immediately the call is switched. The supervisory then supplies ring and ring tone at the usual cadence

* The 4 s time-out period used to determine the end-of-dialling point on current exchanges delays the completion of the transmission path to confirm that dialling is completed



(a) Subscriber to dial tone

(b) Intermediate make-before-break stage of selecting an own-exchange supervisory unit

(c) Selection of own-exchange supervisory unit complete (control not associated)

(d) Path to called subscriber connected, register held

(e) Call established

FIG. 2—Trunking of an own-exchange call in UXE7

General

Slide-in-units, using conventional or printed wiring as appropriate, are mounted on one of two basic rack variants: a traffic rack, providing control and switching for 100 subscribers; or a miscellaneous rack, mounting exchange common-supply equipment and miscellaneous facilities. The racks, which are based upon the TI 1000 equipment practice, are 2·33 m high, 0·92 m wide and 0·65 m deep.

One miscellaneous rack and up to 5 traffic racks can be linked together to provide service for up to 500 lines, with a maximum bothway traffic of 60 erlangs.

Principal Equipment Items

The main equipment areas of the UXE8 system are:

(*a*) subscribers' line circuits,

(*b*) reed-relay switch network,

(*c*) electronic solid-state controlling logic,

(*d*) registers, and

(*e*) junctors.

Fig. 3 shows a simplified block diagram of the main equipment areas, which are described briefly below.

Subscriber's Line Circuit

The subscriber's line circuit provides access to the switch network for the subscriber. It also monitors the state of the line, detects calling conditions, which it extends to the control logic, and accepts marking signals. Each subscriber's line circuit contains a diode strapping field for allocation of COS and a remotely-controlled status store for temporary-out-of-service (TOS) conditions.

Reed-Relay Switch Network

The switch network is built up of 5 × 5 reed-relay switch matrices to provide both speech and signalling paths through the exchange. There are 3 stages of switching, as shown in Fig. 3, which are used in the setting-up of calls as follows:

(*a*) *Own-Exchange Calls* The calling line is switched through the A- and B-switches to an originating junctor, and thence via the C-, B- and A-switches to the called line.

(*b*) *Outgoing Junction Calls* The calling line is switched through the A- and B-switches to an originating junctor and thence via the C- and B-switches and an outgoing A-switch to an outgoing junctor.

(*c*) *Incoming Junction Call* (*Terminating*) The incoming junctor is connected to the called line via C-, B- and A-switches.

Electronic Solid-State Controlling Logic

The controlling logic contains the electronic circuits necessary for the identification of a calling line for path-selection, marking, routing and metering. For security reasons, all control circuits are duplicated. The principal circuit blocks of the control equipment are shown in Fig. 3. Calls are handled by the control logic on a one-at-a-time basis but, because of the high speed of the electronic logic operations, handling of calls in this sequential manner produces no significant delay.

Registers

Information relating to a call, including the called directory number and subscriber's COS is stored in the registers. The

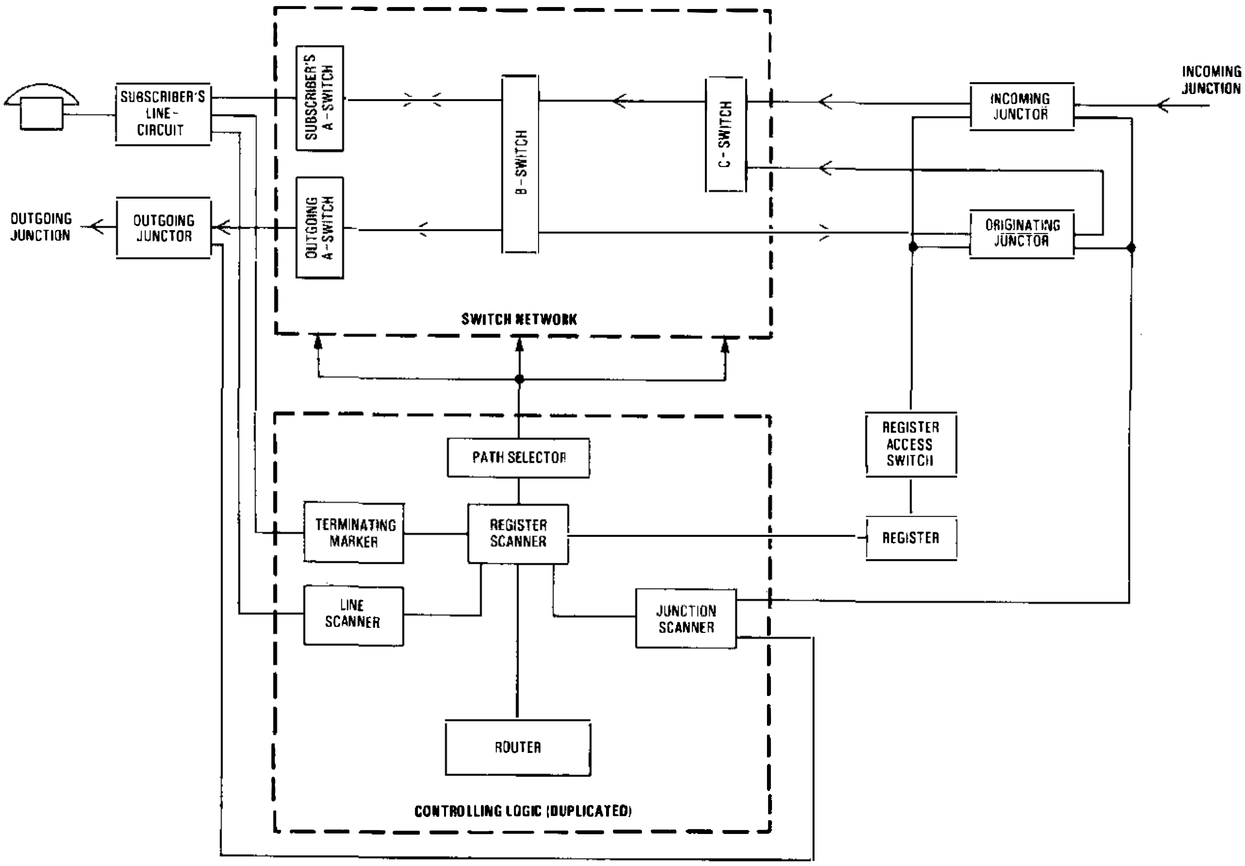


FIG. 3—Block diagram of the UXE8 system

registers also convert dialled impulses into coded information suitable for application to the router. The registers are connected to the junctors by the register access switch.

Junctors

Junctors provide the transmission feed and bridge, ringing current, and supervisory tones; they supervise the call after setting up, control the metering of calls, monitor the end of a call, and arrange for the release of circuits. Junctors are of three basic types to cater for incoming, outgoing and own-exchange calls with options as required for various signalling systems and facility requirements.

System Operation

Call Origination

When the caller lifts his handset, the calling signal is detected by the associated subscriber's line circuit. The line scanner addresses each line circuit sequentially. When the calling line circuit is addressed, it sends a signal to the line scanner to stop on its address. Whereupon, the line scanner sends a *scanner-stopped* signal to all registers.

Registers are sequentially addressed by the register scanner; the first free register stops the scanner when it is addressed and marks the calling line circuit. Clock pulses are then sent to the calling line circuit to extract the calling-subscriber's COS and state of line. This data is stored in the register and validation checks are applied; if the COS is valid, the register marks its register access switch and sends an *interrogate* signal to all originating junctors.

All free originating junctors on the rack containing the calling line respond to the *interrogate* signal from the register by sending to the path selector a signal that indicates the B-switch unit to which they are connected. The path selector selects a B-switch unit that has a free A–B link and at least one free originating junctor; it then connects a *mark* signal to the selected A–B link and sends an *enable* signal to the originating junctors connected to the selected B-switch. The junctor scanner sequentially addresses all originating junctors (and outgoing line signalling circuits). When the first enabled junctor is addressed, the scanner stops and the selected junctor connects a *mark* signal to the B-switch and to the register access switch.

At this point, the A-switch and B-switch crosspoint relays operate; they connect the positive, negative and P-wires from the subscriber's line circuit to the originating junctor and, thence, to the register via the register access switch. The register checks for continuity of the positive and negative wires and then causes the junctor to send an earth signal on the P-wire to operate the K relay in the subscriber's line-circuit. Successful operation of the K relay sends a *path switched* signal to the register; relay A in the register then operates to the subscriber's line loop. The register and path selector suppress their *mark* signals, which allows the scanners to be released to deal with further calls, and the register returns dial tone to the subscriber.

On receipt of the first digit, the register removes dial tone and loads the digit into its first digit store. The register then sends the digit to the router, which produces a translation to indicate whether the call is own-exchange or outgoing.

Own-Exchange Calls

When an own-exchange call is indicated, the register waits for the remaining digits to be dialled. It stores these and enters the termination phase of the call. The originating junctor adopts a bridged configuration. After the final digit has been dialled, the register sends the last 3 digits dialled to the terminating marker. If the dialled number is spare, the terminating marker produces an invalid code signal; this causes the register to return number-unobtainable tone for 20–40 s, followed by force release if the handset is not replaced. If the dialled number is valid, the terminating marker marks the called-subscriber's line-circuit.

The register sends clock pulses to the called line circuit to extract the COS and state-of-line data. If this data is valid, the register sends signals to the originating junctor to indicate that the call is to be connected to a subscriber and to cause the junctor to mark its C-switch. The C-switch mark allows the path selector to monitor the *free/busy* status of the B–C links. The path selector then chooses and marks a B-switch unit having free A–B and B–C links. The C-switch, B-switch and A-switch crosspoint relays operate, connecting the negative, positive and P-wires from the originating junctor to the called line-circuit. Completion of switching causes the called-subscriber's K relay to operate and return a *path-switched* signal to the register.

The register signals the originating junctor to take over supervision of the call (ringing, metering and clear-down) and then releases; this frees the register and scanners for further calls.

Outgoing Calls

If, in response to the first digit or digits, the router indicates that an outgoing route is required, the register sends an *interrogate* signal to all outgoing junctor circuits connected to the required route. The junctor scanner stops on the first interrogated outgoing junctor that is free and the selected circuit passes a *state-of-line* signal to the register. The register causes the outgoing junctor to mark the outgoing A-switch units and the originating junctor to mark its C-switch unit. The path selector then chooses and marks a B-switch unit having free A–B and B–C links.

At this point, the C-switch, B-switch and outgoing A-switch crosspoint relays operate, connecting the positive, negative and P-wires from the originating junctor to the outgoing junctor. The originating junctor signals completion of switching (all paths checked) to the register on the state-of-line highway, and the register and path selector suppress their *mark* signals, allowing the scanners to be released for further calls. The originating junctor adopts a bridgeless configuration for outgoing calls.

As the first digit or digits required at the distant exchange may have been used to define the outgoing route required, these digits are stored in the register. The register therefore commences to send the digits required by the distant exchange as further dialled digits are concurrently received from the calling subscriber. For calls to the parent GSC, the register can be programmed to insert a single digit to define the charge area of the exchange and the class of caller (ordinary or coin-collecting box (CCB)).

During the sending of digits, the register monitors for a "catch-up" situation. When this condition is detected, the register switches through so that any further dialled digits are sent over the junction under direct control of the subscriber's dial.

Incoming Calls

When an incoming junction call occurs, the incoming junctor sends a *priority* signal to the line scanner, which prevents the scanner from stopping on any subscriber's line circuit. The line scanner addresses the incoming junctors sequentially and is stopped when it addresses the one that is calling, whereupon the line scanner sends an incoming *stop* signal to all registers, together with an incoming *priority* signal. The first free register stops the register scanner when addressed, the *priority* signal ensuring that preference is gained over other registers requiring register scanner control.

The register sends clock pulses to the incoming junctor to extract the COS and state of the incoming junction. If the COS is valid, the register marks the register access switch and the crosspoint relay operates to a *mark* signal from the incoming junctor, connecting the negative, positive and P-wires from the junctor to the register. The register checks the switch path for continuity and then connects a signal to the P-wire, which causes the incoming junctor to connect the incoming junction to the register. The A relay of the register then operates and is subsequently controlled by the distant subscriber.

At this point, the register suppresses the *mark* signal, freeing the scanners for use on the next call, and awaits incoming digits. (Note that dial tone is not connected.)

The call terminates as previously described.

First-Off Installation

As the BPO had no in-service experience of UXE8, the first-off installation at Wigtown, in South West Scotland, was subjected to special tests to demonstrate all features and facilities prior to entering service on 22 May 1980.

FACILITIES

The UXE 7 and 8 can provide a wide range of facilities to cater for subscriber and BPO administrative requirements, including multi-frequency Keyphone, CCB, shared service, subscriber-controlled transfer, remote test and remote control of TOS.

MAINTENANCE ARRANGEMENTS

The exchanges will be arranged in maintenance areas that consist, depending on the location, of 5, 6 or 7 exchanges. Each maintenance area will have one of its UXE7/8 exchanges nominated as a Maintenance Centre, which will be fully equipped to enable all plug-in units to be faulted and repaired. In the case of the UXE8, a back-up service will be available at the STB/Edinburgh Area Repair Centre on a Membrain diagnostic tester.

Each exchange has facilities to send fault print-out data over the public switched telephone network to a common point for each maintenance area. This common point could be the Maintenance Centre but may be elsewhere if staffing arrangements are more convenient. Remote interrogation of alarm category is possible for both systems.

Spare units, necessary to restore service (that is, for non-duplicated equipment). are held at each exchange and spares of all other units are held at each Maintenance Centre.

CONCLUSIONS

While the limited purchase of UXE7/8 exchanges will make only a small impression on the modernization programme it will provide the BPO with valuable experience of the training requirements, installation procedures and maintenance/operating arrangements for groups of small modern exchanges in some of the more remote areas of the BPO network.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of GEC and Plessey personnel in the preparation of this article.

References

[1] LONG, R. C., and GORRINGE, G. E. Electronic Telephone Exchanges: TXE2—A Small Electronic Exchange System. *POEEJ*, Vol. 62, p. 12, Apr. 1969.

[2] MOON, R. J., TARRY, D. G., and BEALE, G. A. TXE2 Electronic Exchange System—The Evolution from Mark 1 to Mark 3. *POEEJ*, Vol. 69, p. 210, Jan. 1977.

[3] BROOKS, B. M. G., and BELENKIN, A. M. Plessey Pentex Installation in the UK Network. *POEEJ*, Vol. 72, p. 186, Oct. 1979.

System X: Subsystems

Part 2—The Network Synchronization Subsystem

R. A. BOULTER, B.SC., C.ENG., M.I.E.E.†

UDC 621. 395. 34: 621. 395. 74

The role of a network synchronization subsystem (NSS) is to provide a secure timing reference at each exchange in the System X network so that all exchanges operate at the same frequency. This article describes the principal features of an NSS and its interaction with the digital network.

INTRODUCTION

The network synchronization subsystem (NSS) will provide a secure and synchronized timing source at System X exchanges to ensure that the clocks in all exchanges in a System X network operate at the same frequency. A 4-level hierarchy of exchanges will be used for network synchronization: at the top level there will be one national reference exchange containing the reference clock; two intermediate levels will contain the main-network exchanges; the fourth level will contain all System X local exchanges and concentrators.

In the absence of network synchronization, the clocks in the exchanges of a digital network would function at slightly different frequencies, which would cause frame slips to occur at regular intervals at the input of each exchange. The effect of these frame slips on the service provided would vary considerably and would depend on the rate at which these slips occur and the type of service being carried; for example, telephony, data or facsimile. Thus, for the British Post Office (BPO) to progress towards the introduction of an integrated services digital network, it is essential that the clocks in the network are synchronized.

NETWORK SYNCHRONIZATION SUBSYSTEM

The network synchronization subsystem consists of two main items: a timing unit (TU), which drives the exchange waveform generators; and a synchronization utility (SU), which maintains the long-term mean frequency of the local TU to that of the other TUs in the network, the absolute frequency of which is determined by the network reference clock[1]. A previous article[2] has discussed the need for synchronization and the network topology requirements. From these requirements, it can be seen that different synchronization equipment is required at a local exchange to that required for exchanges in the main network.

In the main network, the security of an exchange TU and the synchronous network is more stringent than that at local exchange level. It is also desirable that, under fault conditions, there is a low risk of the formation of separate individual synchronized sub-networks. To this end, a mixture of double-ended unilateral and bilateral links are used to establish mutually synchronized levels in which the effects of faults are prevented from spreading to other parts of the network and in which the number of links necessary to give the required reliability is reduced. In contrast, the local exchanges use single-ended unilateral control and are simply slaved to their parent main-network exchange.

MAIN NETWORK SYNCHRONIZATION

A block diagram of the NSS equipment provided at digital main-network switching centres (DMNSCs) is shown in Fig. 1.

The Timing Unit

The basic unit of the TU is a 4·096 MHz high-quality quartz-crystal oscillator which is frequency controlled and which incorporates a frequency doubler; all components are contained within a temperature-controlled oven. The oscillator has an electrical tuning range of ± 1 part in 10^6 and an ageing rate of less than 2 parts in 10^8 per month. However, since the failure of the TU causes the loss of calls through an exchange, an unsecured crystal oscillator of this kind is not sufficient. Therefore, 3 crystal oscillators are used to provide a secure supply: one acts as the worker; the other 2 operate in the standby mode.

In normal operation the worker oscillator is phase-locked to the digital network (provided that the exchange is not isolated from the main digital network) and the two standby oscillators are phase-locked to the worker. The phase-locking of the standby oscillators is provided to minimize the phase step in the TU output on change-over from the worker to either of the standby oscillators. The phase-locking is achieved by the application of *advance* or *retard* control signals to the frequency control of the oscillator. These signals cause an advance or retard in the natural frequency of the oscillator by 1 part in 10^6 for the duration of the pulse. The signals derived by the SU to synchronize the worker oscillator last for 16 ms and result in a phase correction of 1/30 of a digit; those pulses derived in the TU to lock the standby oscillators are much shorter and more frequent and thus enable a much tighter locking of the oscillator.

The 8·192 MHz signals from each of the 3 oscillators are passed to all 3 change-over switches. Each change-over switch selects the signal from one oscillator only and checks with the other switches to ensure that the same oscillator is chosen by them all. The selected oscillator is known as the *worker*; if it fails, the change-over switches select one of the standby oscillators as a new worker in a cyclic fashion (that is, oscillator A to oscillator B to oscillator C to oscillator A), except that a faulty standby oscillator will not be considered for worker status. Finally, the change-over switch divides the selected 8·192 MHz signal by 4 to produce the required 2·048 MHz signal. Three change-over switches are required to provide triplicated waveforms to the primary waveform generators; these feed secondary waveform generators in the digital switch which are distributed over a number of racks and shelves. A simple majority decision can then be used to provide security to the waveform generators in the event of failure in the change-over switch or in the waveform distribution.

The CCITT* Recommendation G811 states that a maximum phase discontinuity in any period up to 2^{11} unit intervals at the outputs of a digital exchange should not exceed $\frac{1}{8}$ of the unit interval (that is, 61 ns at 2·048 Mbit/s). To achieve this, the 3 output waveforms transmitted to the majority decision

† Systems Evolution and Standards Department, Telecommunications Headquarters

* International Telegraph and Telephone Consultative Committee

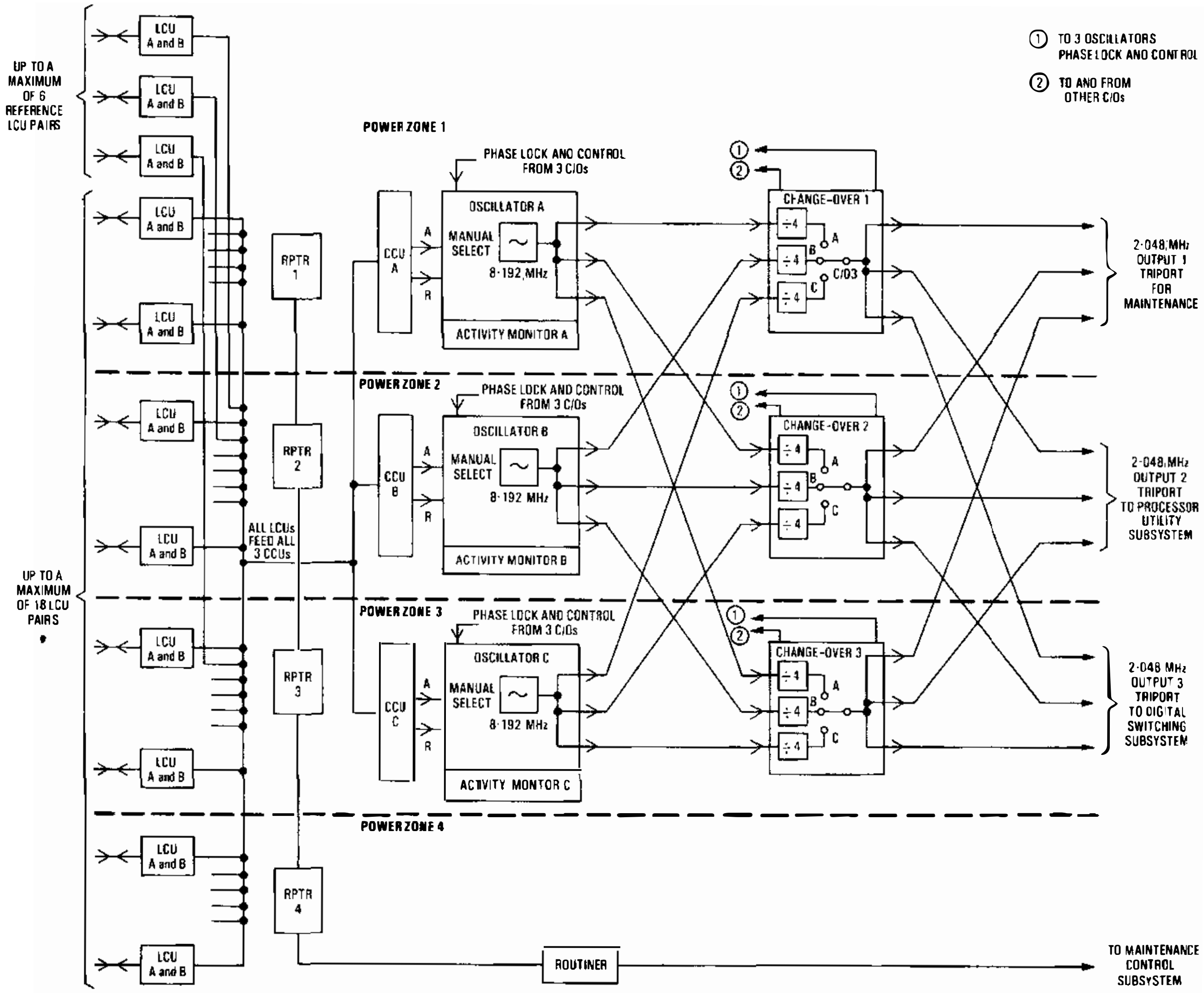


FIG. 1—Block diagram of the network synchronization subsystem equipment in a main network exchange

gates in the secondary waveform generator must be within 61 ns of each other so that, if one generator fails, a discontinuity of greater than 61 ns does not occur. This tolerance of 61 ns covers both the change-over switch and the whole of the waveform distribution; 13 ns of this tolerance is assigned to the change-over switch. The main purpose of the change-over switches is to provide a no-break change-over between the previous worker and the standby oscillator. A change-over is achieved with a maximum phase discontinuity in the oscillator output waveform (at 2·048 MHz) of less than 7 ns. A change-over is initiated and an alarm is raised when any of the following conditions arise:

(*a*) if the selected oscillator fails to provide an adequate output;

(*b*) if the net control activity at the input to the selected oscillator exceeds 33% of its possible maximum value over any 16 s interval (this generally indicates that either the oscillator requires retuning or that the selected control module is faulty);

(*c*) if the net control activities at the inputs to both standby oscillators exceeds 33 % of their maximum value (this indicates that the frequency of the selected oscillator is outside its specified limit);

(*d*) if continuous control activity is applied to the input of the selected oscillator for more than 1·5 s (this indicates that the oscillator is not responding to control signals); or

(*e*) when the service staff wish to free a previously selected oscillator from service so that it can be retuned.

The net control activities mentioned above are the net number of control pulses applied to the oscillator (that is, the difference between the number of advance and retard pulses) expressed as a percentage of the maximum amount of control that can be applied. The net control activities are measured by the activity monitor, which is associated with each oscillator; the activity monitor instructs the change-over switch when it is necessary to cause a change-over.

The Synchronization Utility

The synchronization utility (SU) compares the phase of its local frame vector derived from its own timing-unit with that of the incoming digital streams on the synchronization links. These links are normal traffic-carrying links, but they are designated for use as synchronization links by the synchronization master plan according to the network topology rules discussed in an earlier article[2].

To achieve phase comparison, the incoming 2·048 Mbit/s traffic circuit used for synchronization is routed via the digital distribution frame to a link control unit (LCU) in the SU. In the LCU, a binary signal is derived from the HDB3 signal and is monitored for the frame-alignment pattern, which appears in time-slot zero of the even frames. The original HDB3 signal is routed to the digital switch via the digital distribution frame. From the frame-alignment pattern a remote frame-alignment signal (FAS) is generated. The phase of the remote FAS is compared every 125 μs with the phase of a local FAS, which has been derived in the LCU from the outgoing 2·048 Mbit/s link.

The absolute value of the phase difference is of little importance since the SU is looking only for changes in phase. Consequently, it is possible to introduce a reset operation which, when invoked, sets the phase-difference measurement to the centre of its range. In this way, only a small range of apparent phase differences need be catered for, and only 8 bits are needed to specify the phase difference to within 122 ns.

The reset operation is used when a link is brought into service or when there has been a significant change in the phase of the remote FAS; for example, when a synchronization link is re-routed. The number that must be added to the measured phase difference to set it in the centre of its range is called *the modifier*, and each LCU has facilities for calculating a new modifier when requested and for storing its value. All further reference to phase difference in this article will imply the modified value unless otherwise indicated.

The digitally encoded phase-difference measurements are processed in a digital filter, which reduces the high-frequency variations in the measurement caused by jitter on the remote FAS arising out of the characteristics of the digital line system. The local phase-difference measurement is then subtracted from the remote phase-difference measurement which has been transmitted over a signalling channel from the remote end. Local control signals and an *out-of-limits* signal are then generated, as indicated in Table 1. This subtraction, involving the phase difference at the remote end, cancels out the effect of phase variations on the link due to temperature; this is known as the *double-ended method* of synchronization.

To enable the interchange of information, a signalling channel is provided between the LCUs at each end of the link by using digit 5 in the odd frames of time-slot zero. This provides a 4 kbit/s capacity and enables a 32 bit signalling word to be sent twice during the 16 ms interval between LCU calculations. Since this capacity is more than adequate to carry the 8 bits of phase information, several checks are incorporated in the signalling word. For example, the sense of the local control-signal is passed to the remote LCU, thus enabling the local control-signal to be compared with the remote control-signal. Provided that the signals do not conflict and the link is effective, the control signal will be forwarded to the common control units (CCUs). The signals from all the effective LCUs are examined by the CCUs, which perform a majority decision on the received signals. The resultant signal (an *advance* signal, a *retard* signal or no signal) is then forwarded from the CCU connected to the worker oscillator.

Certain conditions could arise in the LCU that would cause it to pass false control information to the CCU. To prevent such an occurrence, the LCU is declared to be non-operative and control is prevented from passing to the CCU when any incorrect conditions are detected within the LCU; for example, loss of frame-alignment pattern in either direction of the 2·048 Mbit/s digital paths. Also, the local *out-of-limits* signal associated with a particular LCU is monitored, and if the signal persists for 0·5 s the LCU initiates the reset operation and signals the remote LCU via the signalling channel to do the same. After this reset operation, the modified phase-difference should be within one-quarter of a digit of the centre of its range, the *out-of-limits* signal should disappear and no control signal should be present at the output of the LCU. If this is not the case, a fault must be present in the LCU and an alarm is raised.

TABLE 1
Derivation of Local Control and *Out-of-limits* Signals

Result of Subtraction (digits)	Local Control Signal		*Out-of-Limits* Signal
	Advance	*Retard*	
> − 2 and < − 2	0	0	0
> + 2 and < + 4	0	1	0
> + 4	0	0	1
< − 2 and > − 4	1	0	0
< − 4	0	0	1

To provide the security required by the synchronization master plan, a maximum of 18 LCUs can be connected to traffic-carrying synchronization links but, in addition to these 18 LCUs, there are 6 other LCUs which are capable of generating their own alignment pattern, and these need not be connected to a digital line-termination unit in the switch. These latter 6 LCUs can be used for synchronization purposes only and are required to connect the reference clock into the reference exchange timing-unit and to synchronize collocated switching units.

As previously described, the NSS is basically a hardware subsystem which does not rely on interaction with the maintenance control subsystem (MCS) before action is taken to by-pass faulty equipment. However, it is necessary to report faults detected and the action taken within the NSS to the MCS so that faulty equipment can be replaced. Within the NSS, the fault-reporting process is achieved by two units: a reporter unit, which multiplexes all the alarm information for a particular security zone; and a routiner unit, which deals with all the data formating and protocol between itself, the reporters and a NSS software package in the MCS. The routiner is a microprocessor-based unit and, on command from the MCS software, performs the following tasks:

(*a*) reports changes in the fault and status outputs from the NSS hardware;

(*b*) interrogates and reports any requested fault or status conditions to the MCS;

(*c*) carries out routining of some standby and little-used hardware; and

(*d*) activates the front panel keys on the oscillator so that retuning can take place.

The fully-equipped NSS occupies a 3-shelf unit of a rack. The TU slide-in-units and the common control unit are always provided, regardless of the size and importance of the exchange, but the LCUs (a maximum of 24) are provided only as required to meet the synchronization master plan; the majority of exchanges are provided with 5 or less LCUs.

LOCAL EXCHANGE REALIZATION

The size and cost of the synchronization equipment at a local exchange is significantly less than that required at a DMNSC. Therefore, at a local exchange, the synchronization equipment has been incorporated in the local digital switching subsystem; this arrangement is possible because of the lower security requirements needed for the TU and for loss of synchronization. From Fig. 2 it can be seen that only two oscillators, used in worker and standby mode, are provided along with inputs derived from two 2·048 Mbit/s synchronization links, which are used on a main and standby basis. The two oscillators feed triplicated change-over switches, as in the DMNSC, which feed the primary waveform generators.

The local exchange timing unit is slaved to its trunk exchanges, and a 2·048 MHz signal derived in the digital line-termination unit at the end of a 2·048 Mbit/s link from the parent DMNSC is used as the main synchronization source. To protect against failure of this link, the synchronization equipment can also accept timing information derived from

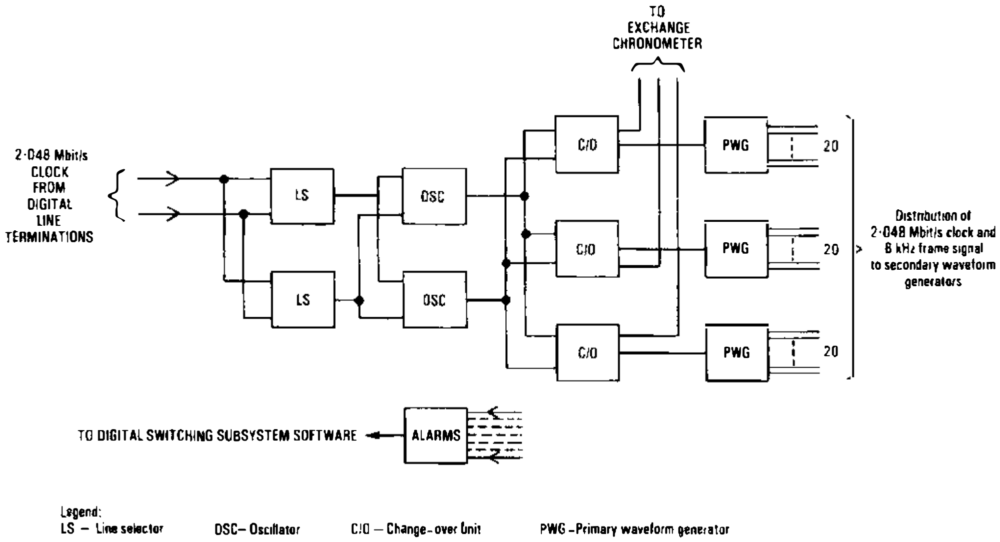


FIG. 2—Block diagram of synchronization equipment at a local exchange

an alternative link. This link would normally be routed from another DMNSC, but if such a route was not available a link to an adjacent local exchange would be an acceptable alternative. Under normal conditions the link to the parent DMNSC is given priority, but in the event of the disappearance of the received clock from this link (for example, if frame alignment is lost), the standby link will control the system until the control is passed automatically back to the main link on its restoration. The 2·048 MHz signal from the selected line is fed into a phase-locked loop associated with each oscillator. The worker oscillator is locked to this signal directly and the standby oscillator is locked via its phase-locked loop directly to the worker oscillator. This arrangement, as in the DMNSC, is made to ensure a minimal phase jump on change-over. The control range of the phase-locked loop is such that a temperature-compensated crystal-controlled oscillator, which has a nominal frequency inaccuracy of 1 part in 10^6, can be used without recourse to temperature-controlled ovens. If both links fail, the phase-locked oscillator is maintained initially to within 3 parts in 10^8 of the network frequency by a memory device in the loop but continues to age at approximately 1 part in 10^6 per year.

The change-over switches (which are triplicated) operate in a similar manner to those in the DMNSC and provide a no-break change-over between the two oscillators and feed the primary waveform generators. The local synchronization equipment is contained within a single shelf, and contains automatic fault-detection circuitry which, when interrogated by the digital switch software, can locate faults to replaceable slide-in-units. No provision is needed for growth and standard equipment is used at all local exchanges, regardless of their traffic capacity or location. Thus, the equipment provides an economical and efficient solution to the problems of synchronization at local exchanges.

CONCLUSIONS

Within the framework of a synchronous integrated digital network, the NSS has an essential role to play to ensure that digital services are not impaired by the regular occurrence of frame slip.

This article has described the operation of the NSS and its application at DMNSCs and local exchanges. Security of operation of the NSS has been achieved by replication of equipment where necessary, and the system offers the highest reliability, even in the face of severe fault conditions.

ACKNOWLEDGEMENT

The author wishes to thank his colleagues in the BPO for their assistance in the preparation of this article and to acknowledge the work of the Plessey development teams in the detailed design of the NSS.

References

1 BUNN, W. National Synchronization Reference Clock, *POEEJ*, Vol. 71, p. 132. July 1978.

2 BOULTER, R. A., and BUNN, W. Network Synchronization, *POEEJ*, Vol. 70, p. 21, Apr. 1977.

The Total-Energy Installation at the Cardiff Telephone Exchange

N. G. JOHNSON, C.ENG., M.I.E.E.†

UDC 621.395.72:620.9

This article describes the design and operational features of a 5 MW power-supply plant that provides the total energy requirements at the Cardiff telephone exchange. Details of the feasibility study and the considerations that led to the adoption of this form of power plant are discussed.

INTRODUCTION

The cost of an independently-generated electrical power supply compared with the cost of electricity purchased from the Electricity Supply Authority does not generally justify the investment of capital by the British Post Office (BPO) in the provision of such power-generation plant. However, if the price differential between the cost of a primary fuel and the cost of electricity is favourable and the waste heat from the power-generation plant can be used for space heating and cooling of a large telecommunications building, then the *total-energy* concept may be viable. The marketing of natural gas supplies from the North Sea provided the incentive for the BPO to assess the profitability of applying the total-energy concept to a telecommunications building.

Before a decision to install a large continuously-running on-site generation plant is reached, it is essential that all the technical factors are fully assessed and that the investment of additional capital be judged commercially sound. A thorough investigation of all the technical alternatives must be made, the demands of local planning authorities satisfied and the proposal financially evaluated. For the feasibility study of such a project to be accepted, it must indicate

(*a*) a high degree of plant reliability,
(*b*) a significant reduction in operating costs,
(*c*) that the staff have the necessary skills for maintaining and operating the generation plant, or that training facilities are available,
(*d*) that security of fuel supplies is adequate, and
(*e*) that the required return on investment capital is achieved within an acceptable period.

† Energy, Transport and Accommodation Department, Telecommunications Headquarters

Fig. 1—Cardiff telephone exchange

Preliminary studies carried out by the BPO in 1971 indicated that a typical 4–5 MW plant operating on North Sea natural gas as the primary fuel would be likely to provide a return of 15–20% on the investment capital over 20 years, and that a pay-back period of 5–7 years could be expected. The study showed that if the gas supply was interrupted, continuity of power supplies to telecommunications equipment could be assured by operating the plant on diesel fuel.

The opportunity to assess the merits of the total-energy concept occurred at Cardiff when the BPO decided to build a 16-storey communications centre (see Fig. 1) adjacent to the existing telephone exchange to cater for main and junction network traffic growth. The substantial level of traffic in the old building and the forecast load growth for the new one provided the load parameters needed, and the planning and provision of a 5 MW plant was commenced.

The new plant, which cost £3·5M at 1979 prices, was commissioned and brought into service in September 1979. A particular feature in the design is the degree of automatic control that has been incorporated to enable the plant to be run unattended for long periods.

THE FEASIBILITY STUDY

Figs. 2 and 3 are taken from the detailed energy analysis

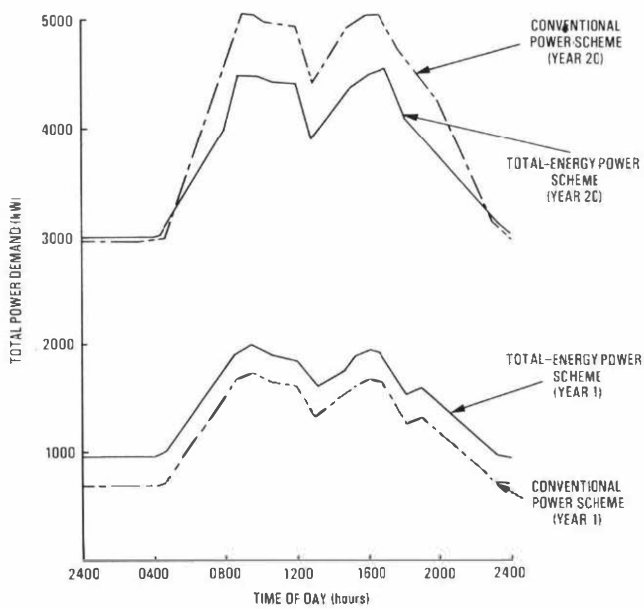


Fig. 2—Forecast of power demand during winter periods

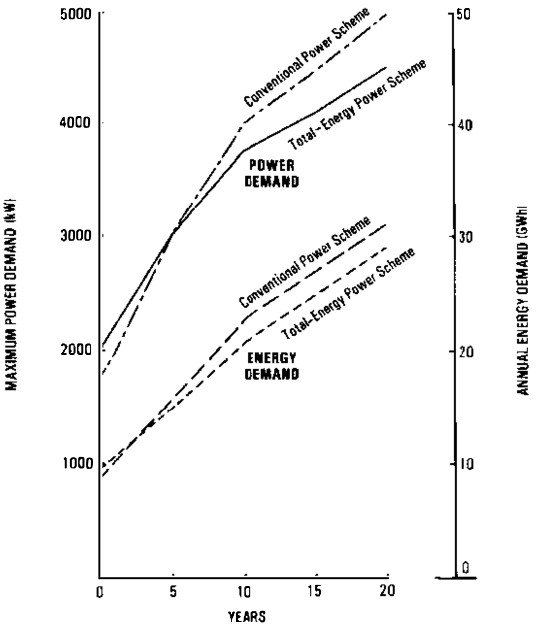


FIG. 3—Forecast of daily power and energy demands

carried out for the Cardiff scheme. Electrical load and heat demand profiles covering hourly, daily, weekly and seasonal energy demands over the 20-year development period were derived. These profiles established that the power requirements for heating and cooling could be met by the installation of six 1300 kW dual-fuel engine generating sets, instead of using an incoming 11 kV mains power supply backed by four 1100 kW generating sets. The use of gas-turbine-driven generating sets was eliminated because of high fuel costs. Two 400 kW electrode boilers, which are used to supplement recovered heat in cold weather, were included for the total-energy scheme. Evaluation of the cooling requirements for the new building indicated that, although two 230 t (1 t refrigeration 3·5169 kW) machines would be sufficient initially, accommodation for 4 water-chilling machines should be allotted.

The initial comparative costings had shown a considerable cost advantage to the total-energy scheme. This cost advantage has since been reduced by unprecedented increases in the cost of primary fuel supplies.

DESIGN CRITERIA

Since in a total-energy scheme the heat energy in the fuel is converted into electrical power at the point of use, the Electricity Supply Authority normally supplies no part of the load. Therefore provision of a mains standby supply would represent an idle power capability which would be paid for at a high standing-charge. For this reason, standby capacity was included in the plant design, and the plant is operated independently of the public mains supply.

The power plant design allows for the provision of 6 generating sets: the station load can be shared between a number of sets, up to a maximum of 4 units; another set is selected to operate in the standby mode; and a further set is available to replace a set undergoing routine maintenance or overhaul. At present, 3 sets are sufficient to meet the load demand; therefore only 5 of the 6 sets have been provided. Sets progressively start up to any preselected sequence and shut down in reverse order to meet load conditions.

If the number of generating sets in operation at any one time is insufficient to meet the station load demand, the fuel selection is overridden automatically and the engines produce an increased power output by the use of the alternative fuel (that is, diesel fuel). Any further shortfall in output is corrected by the progressive load shedding of up to 5 stages of less-essential load. A further control is provided to ensure that a minimum number of sets is retained in operation. The machines generate at 415 V, 3-phase, 50 Hz.

The design has also ensured that

(*a*) the plant is fully automatic in operation and that it can be run unattended outside normal working hours,

(*b*) the provision of fuel and lubricating-oil storage capacity is sufficient for 25 days continuous running,

(*c*) there is no increase in the noise level at the boundary of the site,

(*d*) the control room is designated as a quiet area,

(*e*) a facility is provided to enable two 500 kW mobile generating sets to be connected into the system for possible future use,

(*f*) the installation complies with gas safety regulations,

(*g*) heavy lifting and servicing facilities are available, including a machine-tool equipped workshop, and

(*h*) communication facilities are provided between the working areas and the control room.

DUAL-FUEL ENGINE GENERATING SETS

The dual-fuel engine is a diesel engine that has been developed to run on natural gas with a small pilot addition of fuel oil into the cylinder to obtain ignition. Additional equipment has been fitted to admit gas into the cylinder and to effect automatic change-over between fuels.

The installed generating plant consists of 5 Allen Type GBCS 37E 9-cylinder turbocharged and intercooled dual-fuel engines. The bore and stroke of the engines is 325 mm × 370 mm. Each engine is mounted on a fabricated steel bedplate and coupled to a 10-pole 3-phase GEC brushless alternator, which is controlled by an automatic voltage-regulator of the thyristor type. The alternators are continuously rated to give an output of 1618 kVA at a power factor of 0·85. The machines are installed in a large engine hall which leads into a second area containing the exhaust-heat recovery boilers and water-chilling machines. These areas are completely sealed from the remainder of the accommodation, and internal access into the engine room is obtained through steel doors. A 10 t overhead travelling crane with a 1 t auxiliary lift is installed above the engine positions.

The method of gas admission into the engine cylinder is shown in Fig. 4. The engine is started on distillate fuel oil and the change-over to dual-fuel operation is controlled by a pneumatic logic circuit. In the diesel running mode, the summing lever (see Fig. 4) is held in the ZERO GAS position and the engine speed governor movement is transmitted solely to the fuel-injection pump control-linkage. On change-over to gas operation, the summing lever pivots about its mid point, the gas metering valves open to deliver gas into the cylinder and the fuel pumps close down to the pilot-fuel setting. Smooth change-over between fuels is ensured by means of air reservoirs and restrictor valves. Each engine generator set has a continuous maximum rated output of 1303 kW on dual fuel and 1375 kW on fuel oil. In addition, the engines are capable of delivering 10% overload for 1 h in 12 when they are running on fuel oil.

The generator sets are started by compressed air at a pressure of 2·07 MPa†; the compressed air is distributed on a ring-main system supplied from six 0·7 m^3 air receivers. System working pressure is maintained by 2 twin-cylinder motor-driven compressor sets arranged for lead/lag operation. A manually-started diesel-engine-driven compressor set is provided for emergency use. Timed-cycle motor-driven lubricating oil priming is fitted to each engine. This pressure primes engines selected for duty for 5 min in every hour and when the engines are started. Engines numbered 1 and 4 are also equipped with supplementary compressed-air motor pre-start priming. Once the engines are running, the lubricating-oil priming system is decommissioned and the engine-sump lubricating oil is replenished automatically from a 4500 litre

† Equivalent to 300 pounds per square inch (PSI)

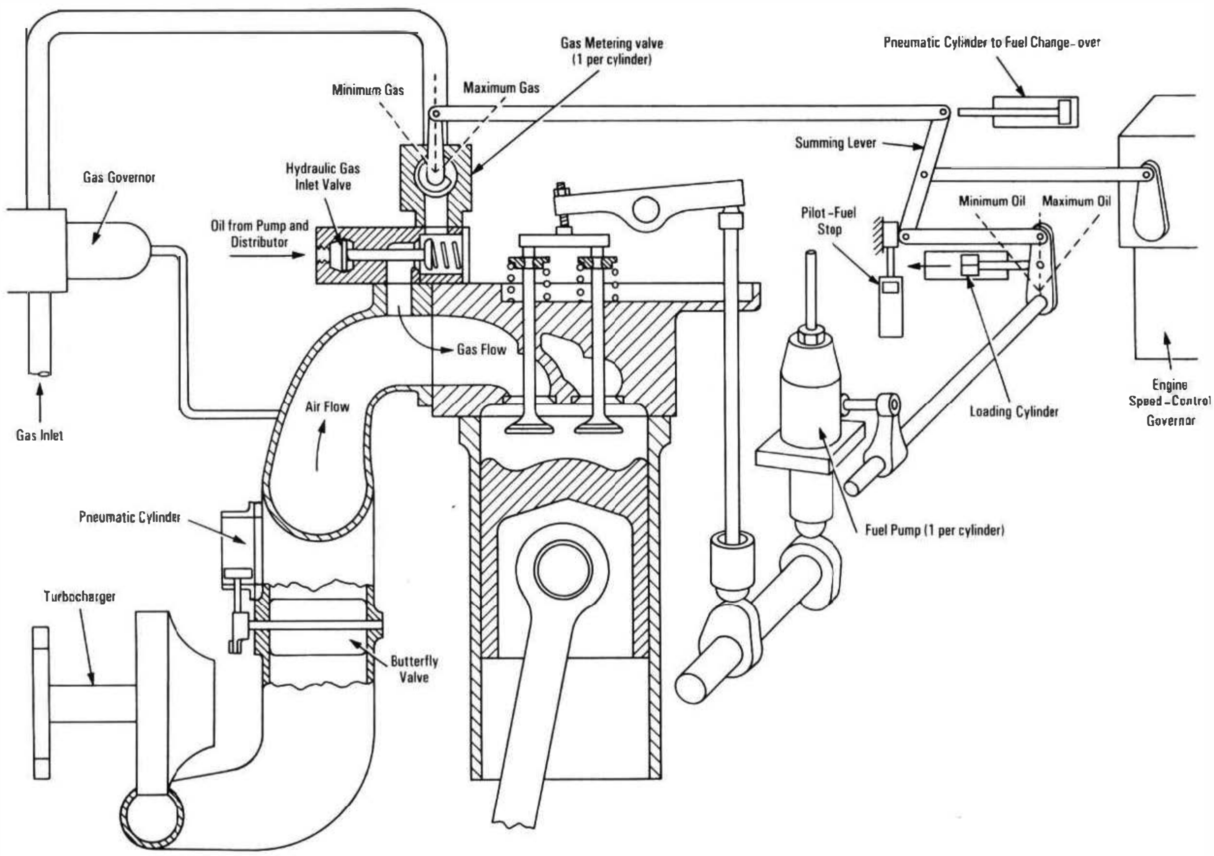


FIG. 4—Engine-fuel selection control

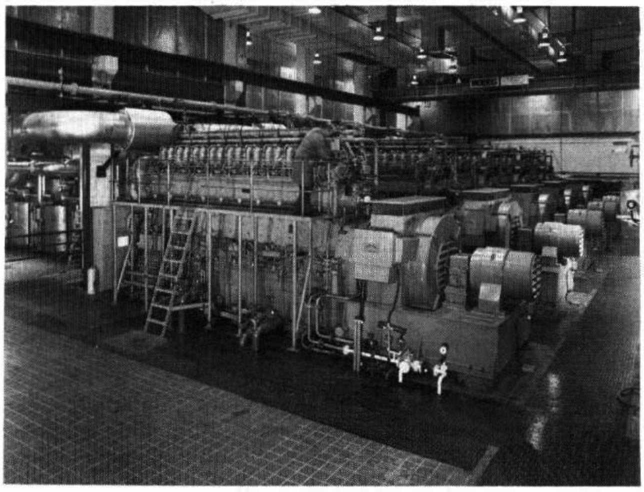


FIG. 5—Engine hall

service tank. A view of the engine hall is shown in Fig. 5.

GAS AND FUEL-OIL SUPPLIES

Natural gas at low pressure is supplied to three gas-compressors, each rated at half the total duty, which are installed in independently-ventilated accommodation. Slow-speed, water-cooled, double-acting reciprocating compressors, equipped with gas after cooling, are installed. Each compressor is capable of delivering 1058 m^3/h to a working pressure of 345 kPa (50 PSI) and each is driven by a 75 kW flameproof motor. The gas is supplied into two 3·85 m^3 gas receivers. Pressure controls start individual machines at set pressure levels, and the system pressure is maintained by a series of spill-back and compressor unloader valves. Abnormal pressure conditions, no ventilation air flow, gas-detector operation or compressor faults initiate action to shut down and isolate the system and to arrange for the safe discharge of gas from the engine supply pipeline. In this latter circumstance, the engines will change to oil operation automatically.

A total fuel-storage capacity of 572 000 litres is provided in welded steel tanks located in a fuel chamber; a 9100 litre main lubricating-oil storage tank is also provided. Fuel and lubricating oil are transferred by motor-driven pumps to service tanks accommodated in a bunded mezzanine enclosure within the engine room and are gravity fed to the engines. The fuel used is diesel oil to Class A of British Standard BS2869.

POWER DISTRIBUTION

Power is distributed to the 16 floors of the new Cardiff exchange building by four 1600 A low-impedance busbar trunking systems with composite local fuse, switch and distribution units. A short section of the system was tested before production and withstood the design short-circuit rating of 60 kA for one second and a peak short-circuit current of 145 kA for 70 ms. Link disconnexion panels are provided at intermediate points on each riser to enable a section to be isolated, and a partial supply can be maintained to selected sections by cross connexions.

The telephone exchange building adjacent to the new Cardiff exchange is supplied by 3 sets (ultimately 4) of duplicated 3-core paper-insulated armoured and sheathed cable. Phase and neutral alternator cables are constructed of 7 single-core hard ethylene propylene armoured and polyvinyl chloride (PVC) sheathed flame-retardant cables suitable for a maximum conductor temperature of 90°C. To prevent the alternator cables exceeding this temperature under extreme load conditions, the alternator cable trenches and cable void beneath the control room floor are ventilated mechanically. Current balance, over-current and reverse-power alternator protection is also provided.

MAIN AND AUXILIARY SWITCHBOARDS

Incoming alternator supplies are terminated on a Spectar

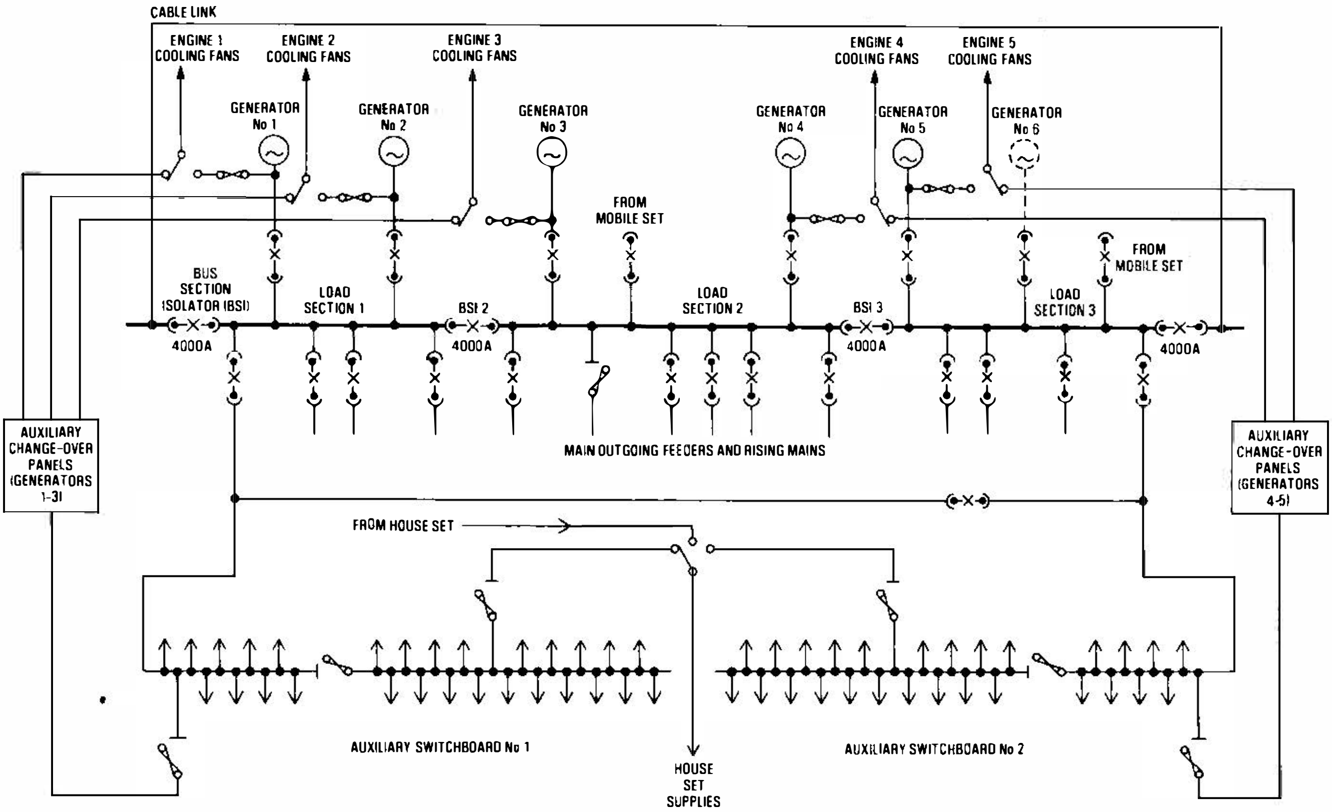


FIG. 6—Block diagram of power distribution arrangements

FIG. 7—Main switchboard

Switchgear 13-panel main switchboard, which is designed to ensure that only 4 alternators can be paralleled at once. The machines' star points are connected to earth. Fig. 6 shows how the switchboard is divided into 3 equally loaded sections, which are normally coupled, and the method of reinforcing the end sections should the centre section have to be isolated. Circuit breakers are of the horizontal withdrawable air-break pattern. All automatic air circuit-breakers are operated electrically from the control panel situated opposite the switchboard or, subject to synchronizing limitations, they can be operated from the breaker itself. Manual closure of the bus section isolator preceding No. 1 bus section circuit breaker is accomplished by an interlocking key (Ronis) arrangement; the cable link, however, is normally kept open. A view of the main switchboard is shown in Fig. 7. Circuit protection for outgoing circuits is provided by inverse definite minimum-time (IDMT) over-current and earth-fault relays. An instantaneous-current element is included in the rising main protection. Trip supervision relays are also used to monitor circuit-breaker tripping supplies.

Two auxiliary switchboards are arranged ensuite with the main switchboard and are supplied from either end of the main switchboard through Castell key-interlocked manually-operated air circuit-breakers. These auxiliary switchboards provide alternative feeding-out facilities to plant and building services. A number of local distribution boards and control panels service individual items of plant.

An auxiliary change-over panel is provided in the engine hall for each generator. The function of each panel is to allow its associated generator to power its own auxiliaries and to restore the auxiliaries to the common supply when that generator is shut down.

HEAT RECOVERY

Provision has been made during the initial operating period for the retention and preferential selection of the existing exchange oil-fired heating boilers in order to provide supplementary heat during cold periods; this is a more efficient alternative to the use of electrode boilers. Use of the oil-fired boilers will be discontinued when sufficient recovered heat is available from the progressive build-up of the telecommunications equipment load. For a similar reason, an absorption chiller and an electrically-driven chiller have been installed initially in preference to two absorption machines.

Table 1 shows the recoverable heat related to the respective load and fuel-rating conditions for each engine set. The recovered heat is supplied to medium- and low-temperature hot-water systems.

The medium-temperature hot-water system operates at a flow temperature of 121°C, and supplies heat from the engine-exhaust waste-heat boilers to hot-water calorifiers serving the existing and the new building conventional hot-water perimeter heating, the absorption chiller and the low-

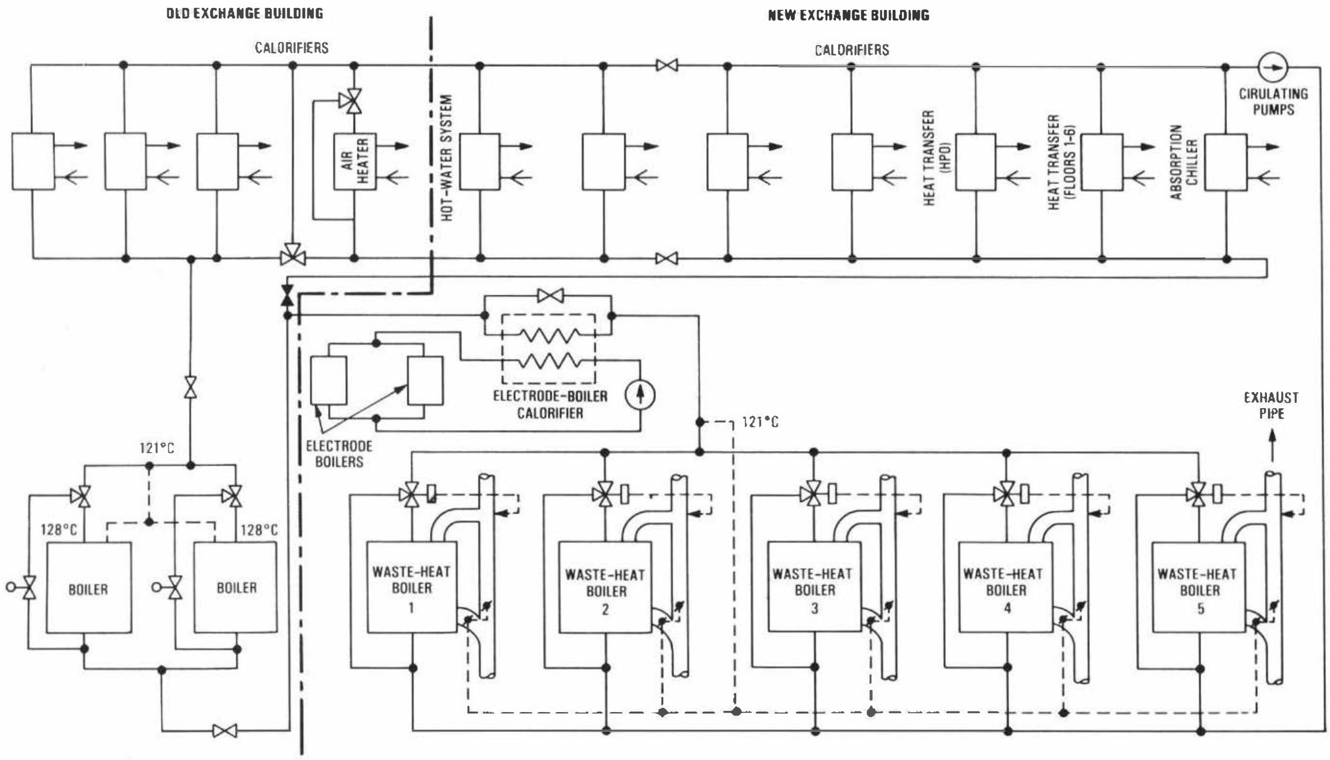


FIG. 8—Block diagram of medium-temperature hot-water system

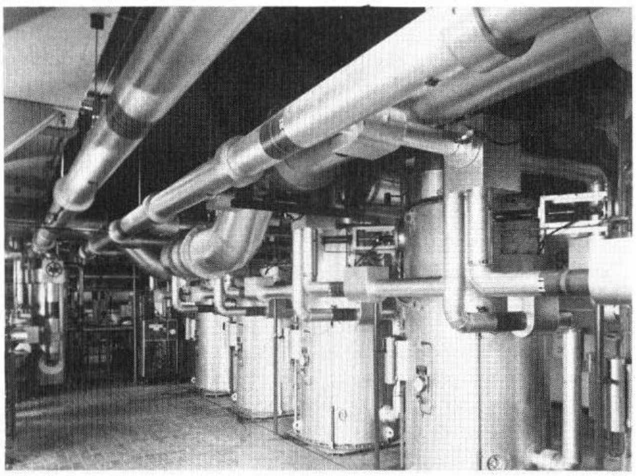


FIG. 9—Waste-heat boilers

temperature hot-water system heat-transfer calorifiers.

Each waste-heat boiler comprises a vertical shell and tube water-heater in which the exhaust gases pass through the tube stack. A 3-way valve in the boiler water flow is held in the minimum flow position until an exhaust gas temperature of 175°C is reached; at this temperature the valve is electro-pneumatically opened to full water-flow through the boiler. The waste-heat boilers are also fitted with a water-cooled pneumo-hydraulic-actuated by-pass valve which allows the gas to by-pass the boiler during periods of low heat demand. Another control operates the by-pass at low exhaust-gas temperatures to maintain the exhaust gases in each vertical exhaust flue above the temperature at which condensation will occur on the tube surfaces. If, at a particular load, the recovered heat is insufficient to meet the demand, an oil-fired boiler or an electrode boiler is switched on. Pressure in the system is maintained by a nitrogen pressurization unit; water conductivity in each electrode boiler is maintained by a chemical dosing set. Fig. 8 shows a block diagram of the medium-temperature hot-water system, and Fig. 9 shows a view of the waste-heat boilers.

TABLE 1
Recovered Heat from each Engine Set

Engine Load (%)	Fuel	Recovered Heat from Engine Exhaust (kW)	Recovered Heat from Engine Water-Jacket (kW)
100	Diesel	632	407
100	Gas	635	410
75	Diesel	435	320
75	Gas	461	322
50	Diesel	298	232
50	Gas	310	234

Space heating for the lower floors of the new building and the Cardiff Head Post Office (HPO) is supplied from the low-temperature system and any heat deficiency is made good by heat transfer from the medium-temperature system. A block diagram of the low-temperature hot-water system is shown in Fig. 10. Heat availability is regulated according to demand, and surplus heat is discharged through a fan-cooled radiator associated with each engine set. The jacket water-calorifier secondaries are connected in series or by-passed if an engine is not running.

Each engine-cooling radiator is divided into 2 sections: the water-jacket section, and a water-to-air section for cooling engine lubricating oil and charge air; six 9 kW thermostatically-controlled fans are fitted to each radiator. Radiators are installed in their own acoustically-lined compartments, which incorporate attenuators in the inlet and discharge air streams.

VENTILATION

Ducted fresh-air ventilation to the engine hall is provided to dissipate radiated heat and to supply engine aspiration air. Four main supply fans and 3 extract fans are used to give one complete air change every 3 min.

A balanced supply-and-extract system, fitted with a differ-

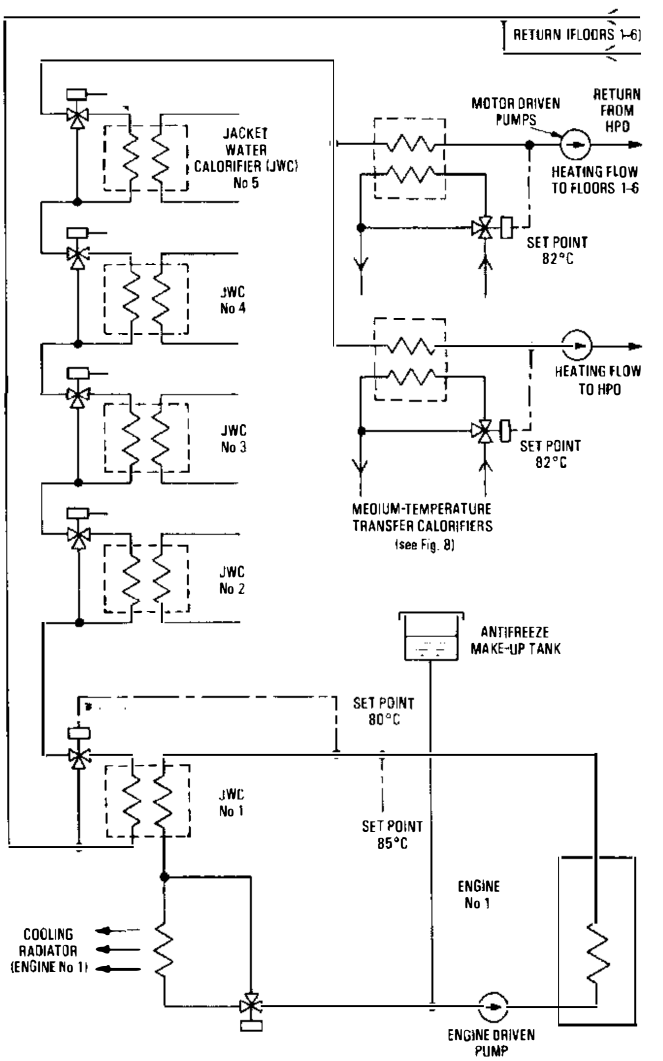


FIG. 10—Block diagram of low-temperature hot-water system

ential pressure switch across each fan set to prevent the compressors running under no flow conditions, is installed in the gas compressor room. All power and control cables leading from the engine hall into the cable void below the control room are sealed against gas entry; the void is ventilated mechanically. The control room is supplied with cooled air from the building system.

CHILLED-WATER MACHINES

The chilled-water machines are hermetically-sealed and connected in parallel to chilled-water rising mains; they are supplied with separate condenser cooling water from evaporative cooling towers.

An electrically-driven centrifugal chiller has an impeller to develop the pressure necessary for the refrigeration cycle. Machine capacity is controlled by guide vanes, and safety controls shut the machines down under fault conditions.

In the absorption machine, a lithium bromide solution is used as the absorbent and water as the refrigerant. Heat carried with the refrigerant vapour from the evaporator into the absorber is absorbed by the solution and transferred to the condensing water. The diluted solution is pumped to the concentrator where heat from the medium-temperature hot-water system boils the refrigerant, which is then condensed in the condenser section and returned to the evaporator. The reconcentrated solution flows back into the absorber for reuse. Capacity control is achieved by modulating the heat input in response to chilled-water temperature.

AUTOMATIC GENERATOR CONTROL

Controls for the generators are accommodated in a suite of control cubicles. The control system operates from a 50 V DC supply and uses plug-in relays and printed-wiring boards mounted on chassis units.

The control equipment, supplied by Regulateurs Europa, constantly monitors the station load to call up, start, synchronize and switch-in sets to load and to shut-down sets no longer required. The call-up and shut-down procedure is shown in Fig. 11.

If an engine set that has been selected automatically fails to start, it will be locked out after one attempt and the next set in the starting sequence will be used. Call-up levels of reserve sets are pre-set at between 80% and 85% of engine load capacity to provide an adequate reserve of power, and the engine-start order is pre-determined by an illuminated push-button matrix. There are 4 other push buttons which can be activated to determine the minimum number of machines to be kept running.

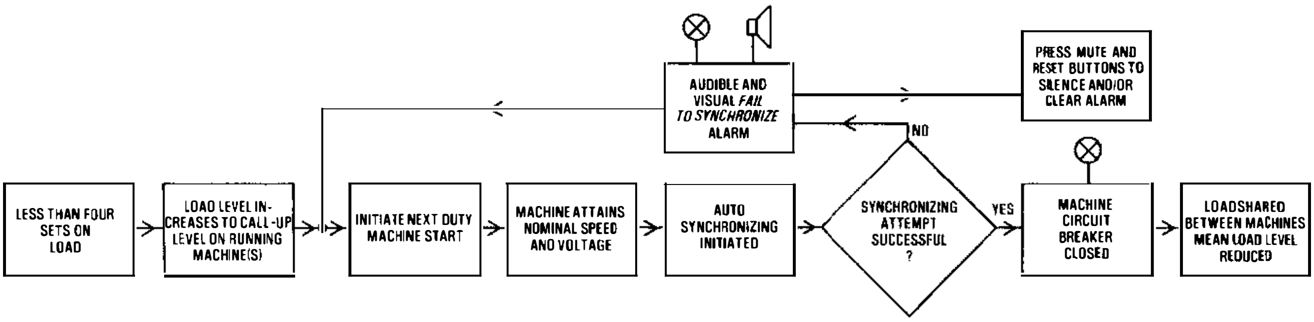
Two automatic synchronization units are provided; either of these may be switched into service. Reference voltages from active machines are converted to a DC potential that is proportional to, and polarity dependent on, the supply difference which is used to raise or lower the voltage by an equalizing amount preparatory to synchronizing. A square waveform which is inversely proportional to phase displacement is also derived and used to apply speed-correcting pulses to the engine governor motors. As the slip frequency between the supplies decreases, a thyristor is fired to initiate a *circuit-breaker close* signal, after which the synchronizer remains inactive until reset by the removal of one of the supplies.

A portable synchronizing unit, mounted on a trolley, is provided to enable machines to be manually synchronized or to allow main load sections to be resynchronized after a bus coupler is opened. If either bus coupler should be opened, the control system reverts to manual control and load sections are supplied independently.

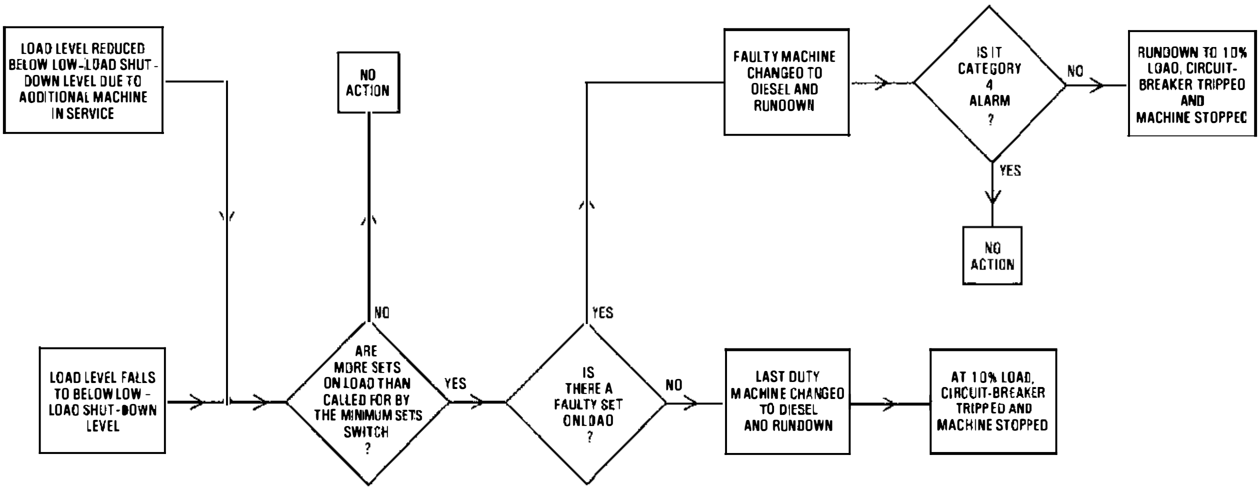
The load on individual machines is compared with the mean load-level of the alternators in use, and the engine governor speed setting is advanced or retarded to share the load equally between machines to ±5% of the mean value.

A close-limit frequency monitor controls alternator frequency by comparison with a stable reference, which is derived from a crystal-controlled oscillator to give a directional speed-adjusting pulse. The monitor works in conjunction with a differential clock system to provide frequency/time error-correction. A crystal-controlled oscillator drives a master clock, accurate to ±2 s per month, which is compared to station time to accumulate the difference in the number of pulses received by master and station clocks. When an error difference of 3 s has accumulated, a corrective input is applied to the frequency monitor to increase or reduce the amount of speed correction until the time error is eliminated. The digital clock can be called upon to display master, station or differential time.

Engine fuel selection for each engine is determined by the position of a selector switch. A selection for dual-fuel (gas) operation will start and shut down the engine on diesel fuel through the operation of the engine pneumatic logic. The flowchart given in Fig. 12 shows the sequence of events when the fuel selection is changed. A fall in frequency by more than 4% when the engines are running on diesel fuel will energize the preference load-tripping circuits sequentially until the frequency is restored. Load sharing and the system frequency are monitored continuously and, if either should exceed operational limits, the automatic control system reverts



(*a*) Call-up of a reserve machine under conditions of high load



(*b*) Low-load shutdown sequence

FIG. 11—Control sequence for bringing machines on and off load

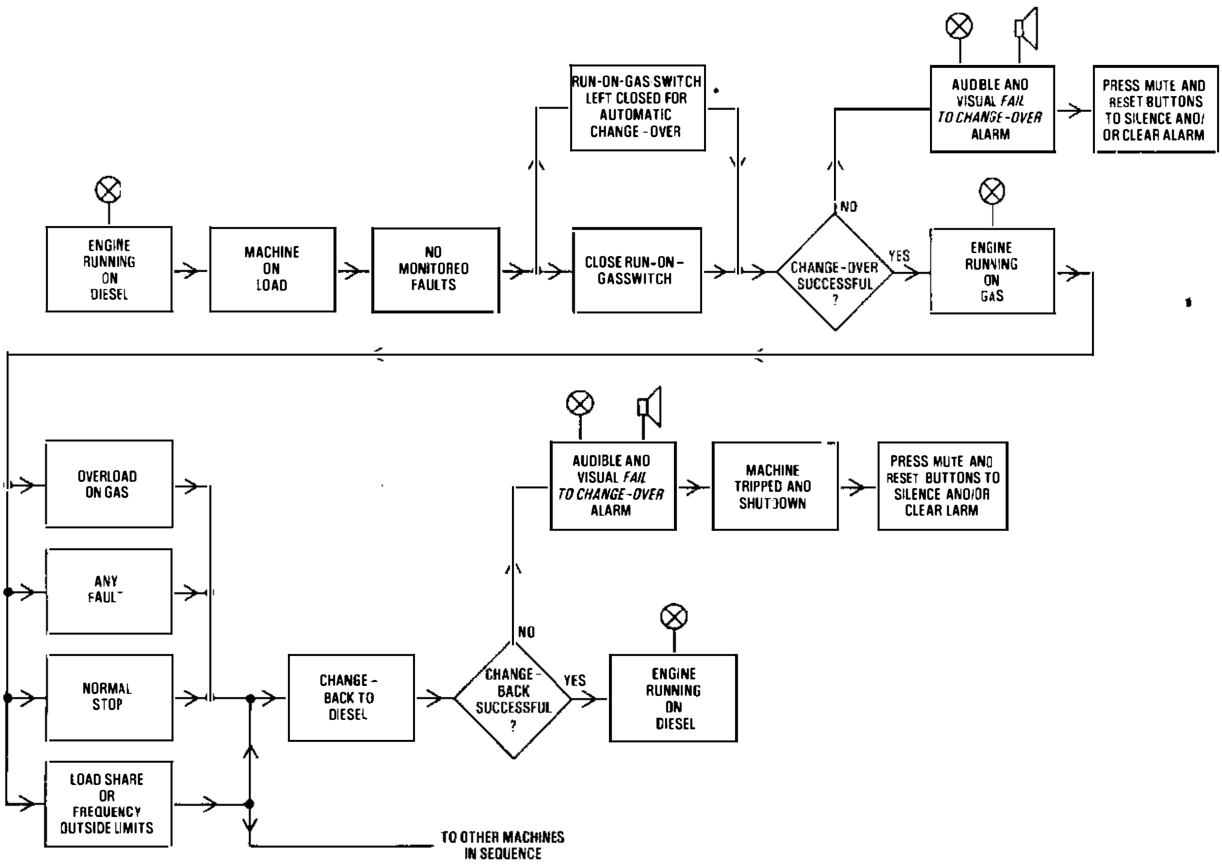


FIG. 12—Block diagram of dual-fuel operation

to manual control until the position is rectified.

An extensive visual alarm system, which includes thermal and electrical mimic-graphic diagrams equipped with flush indicating lamps and dolls-eye semaphore circuit-breaker position indicators, has been provided. A monitored fault condition causes the appropriate fault lamp to flash and a protection healthy lamp to be extinguished. The audible alarm is silenced when the fault is accepted by the maintenance staff and fault-lamp indication becomes steady. Except in the case of maintenance-attention alarms, which are self resetting, fault lamps remain lit until the fault is cleared.

Engine fault conditions are divided into 4 categories: category 1—alarm and immediate shut down; category 2—alarm and subsequent shut down; category 3—alarm and 15 min shut down, and category 4—alarm only. A category 3 fault condition is applicable only to the last set in the automatic mode of operation and to all sets when under manual control.

Alarms are extended during periods when the station is unattended; these alarms are grouped to indicate plant faults, fire alarms and gas-detection alarms.

Other cubicles contain instrumentation and controls for remotely-operated mobile generating-sets, remote pressure gauges, fuel contents gauges and common equipment alarms. One cubicle accommodates spare circuit-chassis units which can be used to restore a faulty unit, thus enabling a machine to be quickly restored to service in the event of a fault.

A local engine control panel is located close to each engine and contains the engine pneumatic logic controls, a duplicate alarm indicator panel (which is slaved from the engine control cubicle), alternator bearing temperature indicating and alarm equipment, various pressure and temperature indicators and an exhaust-gas and turbo-charger monitoring unit; this latter unit indicates high or low deviation from average cylinder temperatures. The engine can be run from the local panel by means of a permissive key-locking switching arrangement.

Compressed air for pneumatic controls is supplied from a separate duplex air-compressor. The compressed air is passed through a refrigerated air-dryer before being reduced to the required control pressure. The compressor is interconnected to a similar building-services compressor to ensure that each compressor has a standby supply.

DATA PROCESSOR

A Honeywell Delta 1000 programmable information-and-control system has been installed; the central processor unit (CPU) is linked to a number of data gathering panels (DGPs) by a digital transmission system. An operator's terminal, a printer and a 35 mm random-access slide projector have been provided.

The DGPs are connected to sensors that measure flow and return water temperatures, flow rates, exhaust-gas temperatures, or detect the operating status of heating boilers, circulating pumps and chilling machines. Several inputs are connected to each DGP. The CPU requests readings from the DGPs at regular intervals.

The selection of the centrifugal and absorption chilling machines according to load demand and heat availability is computer controlled, as is the switching of the electrode boilers. Information derived from the sensors is printed-out twice daily and calculated heat-loads in kilowatt hours at monthly intervals. High or low alarms are printed in red and include the time of occurrence; such print-outs take precedence during a routine print-out sequence. An operator may type in the appropriate sensor identification code to obtain a visual display or call for a print-out of readings. An interface is provided to drive the lamps on the mimic diagram. The CPU is programmed by a cassette tape.

GAS DETECTION

Natural gas can explode only when in a concentrated form in the presence of air. Normally, the ventilation system will rapidly disperse any formation of gas but, for additional protection, 35 gas detectors have been installed. The detectors incorporate a catalytic pellistor sensing element and, to ensure stability of operation and long life, they are each limited to a sensing time of 10 s in every 4 min.

Two types of gas-detection monitors have been provided and they incorporate a self-checking facility. For general use a 2-stage detector has been used to give a warning at a 10% lower explosive limit (LEL) and a high setting at 50% LEL. The monitors in the gas compressor and meter rooms are intrinsically safe and are fitted with the 50% setting only. On receipt of the 50% warning, all engines change to diesel operation and the gas in the system is discharged to the atmosphere. A heat detector is also fitted above the engine positions. When operated, the heat detector initiates the shut down of the engine involved and the gas system; the remaining engines are then switched to diesel operation.

EMERGENCY GENERATING SET

A small diesel-engine-driven packaged alternator set is planned which, in an emergency, will power the engine room and control room lighting independently from the main engines.

INDUCTION COMMUNICATION SYSTEM

A 2-channel induction communication system operating at radio frequency over an induction loop aerial has been installed to maintain communication between operating staff in the control room and other plant areas.

Personnel working on the engines and in other noisy plant areas are encouraged to wear special headsets which may be worn within a standard protective helmet. The headsets consist of ear defenders incorporating earphones, a boom-mounted microphone and the associated transmitter/receiver equipment. A locking ON/OFF TRANSMIT key is provided to allow the user free use of his hands. A distinctive alarm signal is given over both channels in the event of a fire alarm.

Equipment within the control room comprises a desk-mounted microphone and fixed transmitter, a loudspeaker/amplifier and the power supply unit. A second loudspeaker is provided in the workshop.

CONCLUSION

There have been marked changes in the absolute and relative cost of electricity, oil and gas since the project was commenced. Energy projections for the future reflect the uncertainties surrounding economic growth, the success of conservation programmes and the drive to maintain the output of indigenous fuels.

The BPO has a contract with the Wales Gas Authority for the supply of gas to the Cardiff installation but, owing to the present economic uncertainties, it is difficult to predict the viability of the project for future years of operation. However, in terms of national energy savings, the higher overall thermal efficiency attained has been estimated by the BPO to represent energy savings for the total-energy scheme amounting to 25% of the energy input required by a conventional scheme over a 20-year period. Experience of the plant in service on fuel oil during the early months of operation has been encouraging, and preparations are in hand to bring the plant into full dual-fuel operation.

ACKNOWLEDGEMENT

The author wishes to acknowledge the contribution made by all his colleagues who have been involved in the project, and to the contribution made by the consulting engineers, Messrs. Kennedy and Donkin.

System X: Design and Support

Part 4—Development Documentation Scheme

B. SHEEKEY, C.ENG., M.I.E.R.E., and Q. G. COLLIER, B.SC.†

UDC 621.395.34: 002

This article outlines the reasons why a new documentation scheme was required for the System X project, having regard to the nature of the System X product and the new commercial arrangement between the British Post Office and its major exchange-equipment suppliers.

The article identifies how the various aspects of the documentation scheme meet these technical and commercial requirements and it explains some of the more significant aspects of the scheme; it also outlines the organizational arrangements required to ensure that the documentation scheme operates effectively.

THE NEED FOR A NEW DOCUMENTATION SCHEME

In order that the various elements of a System X exchange fit together to form an effective system, it is essential that common standards are applied in hardware, software, control methods and support facilities. Documentation is the communication medium used to transfer information and thus, to ensure common understanding, it must also be made standard in its presentation and use. It must be recognized that existing documentation schemes in use within each of the firms participating in the development of System X are structured to match their internal organization and specific ways of working. The various requirements of the participants in regard to documentation are therefore often in conflict; despite these conflicts, the documentation of System X must be usable by each participant.

OBJECTIVES

A modern stored-program-control (SPC) exchange comprises a combination of hardware and software; therefore its documentation must enable these aspects to be brought together to form a coherent system. Parallel development by separate organizations of the constituent parts of a complete exchange system, with complex interactions between these parts, required that the common documentation scheme had to be detailed to an extent which ensured that

(*a*) the design and product documentation was consistent in structure and information level, independent of the source of the documentation, and

(*b*) that all participants could understand the design and each could make the complete designs to the degree of product commonness required by the British Post Office (BPO).

The documentation scheme had also to ensure that

(*a*) changes to design could be effectively controlled[1] and compatibility between the various elements of the total design was maintained, and

(*b*) computer-aided-design information could be managed[2].

Rework of documentation is very costly, and therefore the need to do so has to be eliminated inasfar as possible. The scheme must therefore allow many types of users to access that part of the total information they require. The total information must cover all aspects from the initial design through to operation. Because the scheme is intended to set a new standard for industry, the scheme has to be usable for systems other than System X.

From these broad requirements, a scheme capable of documenting all aspects of System X was developed jointly by the BPO and industry. To aid description in this article, the major elements of this scheme are considered under the headings of coding, documentation structure, document types, change control, database and information interchange. However, in practice, these various elements interact with each other.

CODING

Coding lies at the centre of any control scheme and, in the past, each participant has used a number of coding schemes adapted to his own company's requirements. As part of the establishment of common standards and practices referred to earlier, a coding scheme capable of multilateral use has been developed for System X. The scheme has a number of significant attributes, as follows.

(*a*) The scheme relates not only to hardware but also to all items which require to be identified, including mechanical parts, electrical components, software and standards.

(*b*) The code is of a fixed format suitable for processing by computer or for human recognition.

(*c*) The code relates to both the product and its documentation.

(*d*) The scheme does not, in general, identify the nature of an item in mnemonic form within the code; for example, the letters RES would not appear in the code for a resistor.

(*e*) The code is independent of a particular application, and thus can be used in a number of different applications without the need for recoding (such application information is held on the computer database, as described later in this article).

(*f*) A code is allocated to an item as soon as the need for the item is identified, thus providing the item with a single identity from inception through all subsequent phases of its existence.

(*g*) In addition to allocating multilateral codes (that is, those for which information is interchanged between the participants), the BPO will, on request, allocate *private codes* to the participants for items which are not required to be interchanged multilaterally, such as in-house standards or assemblies which are intermediate stages in a production process. The private codes are identical in format to multilateral codes; this allows the participants to use, within their own organizations, the same mechanisms for handling private

† System X Launch Department, Telecommunications Headquarters

codes as those established for multilateral codes. The only difference is that private codes are not loaded onto the multilateral database.

The code structure consists of alpha and numeric fields, arranged alternately to assist easy recall. An example of the structure of a typical code is given in Fig. 1. With reference to Fig. 1, the significance of the character fields ((*i*) (*v*)) is as follows:

Character Field (*i*)
This single numeric character field helps to avoid possible confusion with a number of documentation schemes already in use which begin with 3 alpha characters. It also indicates the broad scope of the item; for example, different values could be used for (say) non System *X* equipment, export versions, etc. To date however, only the character 1 has been used.

Character Field (*ii*)
This 3 alpha character field, known as the *classification field*, indicates the general nature of the item; for example, whether it is a planar slide-in-unit, a piece part, a software module, etc.

Character Field (*iii*)
This 5 numeric character field, known as the *serial field*, consists of numbers allocated serially from unity and, when used with the variant field (see (*iv*) below), serves to identify a particular item within a classification.

Character Field (*iv*)
This 2 alpha character field, known as the *variant field*, is used to distinguish between items for which there is a large proportion of common documentation (usually because the items are physically similar). For example, for a family of resistors of a given type, the power ratings and the tolerances would all have the same serial, but the individual values would be variants against that serial.

Character Field (*v*)
This single alpha character field, known as the *check digit*, is a digit derived according to a modulo-23 algorithm. Although the check digit conveys no information additional to that given by the other fields, it serves as a valuable safeguard in computer use against data entry errors.

An example of a code in common use is shown in Fig. 2, which indicates the code for a metal-oxide resistor.

A plain-language description of up to 30 characters is associated with each code to provide a meaningful description of the item.

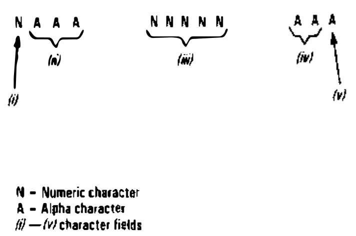


FIG. 1—Code structure

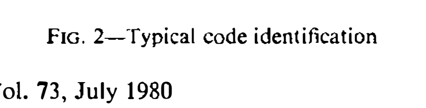


FIG. 2—Typical code identification

All codes are controlled and allocated by the BPO. Applications for code identities are received from engineers in the BPO or in industry and, after checking for errors, the appropriate code is allocated and entered on the multilateral database. At present, the procedure is operated manually by using paper application forms, but the feasibility of an on-line application procedure is currently being investigated.

By the end of 1979, approximately 15 000 codes had been allocated, and the then current rate of allocation was approximately 500 per month.

DOCUMENTATION STRUCTURE

A hierarchical structure has been adopted for the documentation of System X. In this way, information at a given point (or *node*) in the hierarchy is represented in terms of lower-order items and their interrelation. These items are represented in terms of yet lower-order items and their interrelation. This progressive provision of greater detail occurs at discrete levels, and ranges from system level to component level for hardware, and to module level for software.

A hierarchical structure has been adopted for 2 main reasons. Firstly, because of the great complexity of modern systems, presentation of a manageable amount of detail at each of a number of hierarchical levels enhances comprehensibility. Secondly, the structure mirrors the way in which the *top-down* design process adopted for System X works; for example, each system is defined and contracts are let on the basis of a system's constituent subsystems.

A simplified representation of the general documentation structure adopted for System X is shown in Fig. 3. The precise structure adopted for a particular system or subsystem is specified by the design team, who take into account its particular characteristics. The agreed structure is recorded by entering on the database the nodes and the hierarchical relationships between them.

From Fig. 3 it can be seen that the general documentation structure consists of several hierarchies which are interconnected at various points. These are defined as follows.

Functional
Items in the functional hierarchy are defined in terms of the functional elements of which they are composed, over a number of levels from system down to slide-in-unit level for hardware and process level for software.

Hardware
Items in the hardware hierarchy are physically-realizable entities, such as slide-in-units, wired shelf-groups, components, etc.

Software
The software hierarchy contains on-line or off-line programs (or constituent parts thereof) and comprises 2 types of item, known as *source* and *object* software.

The source software is written in high-level language with a direct hierarchical relationship between items: thus a process consists directly of a number of modules.

The object software consists of machine code which can be loaded onto, and run on, a real-time machine or an off-line machine. Object software is obtained from source software by using compilation and linking facilities on the software development facility (SDF)[3].

Standards
Standards may be referenced from any node; the database, in addition to showing direct hierarchical relationships, has facilities for identifying such references.

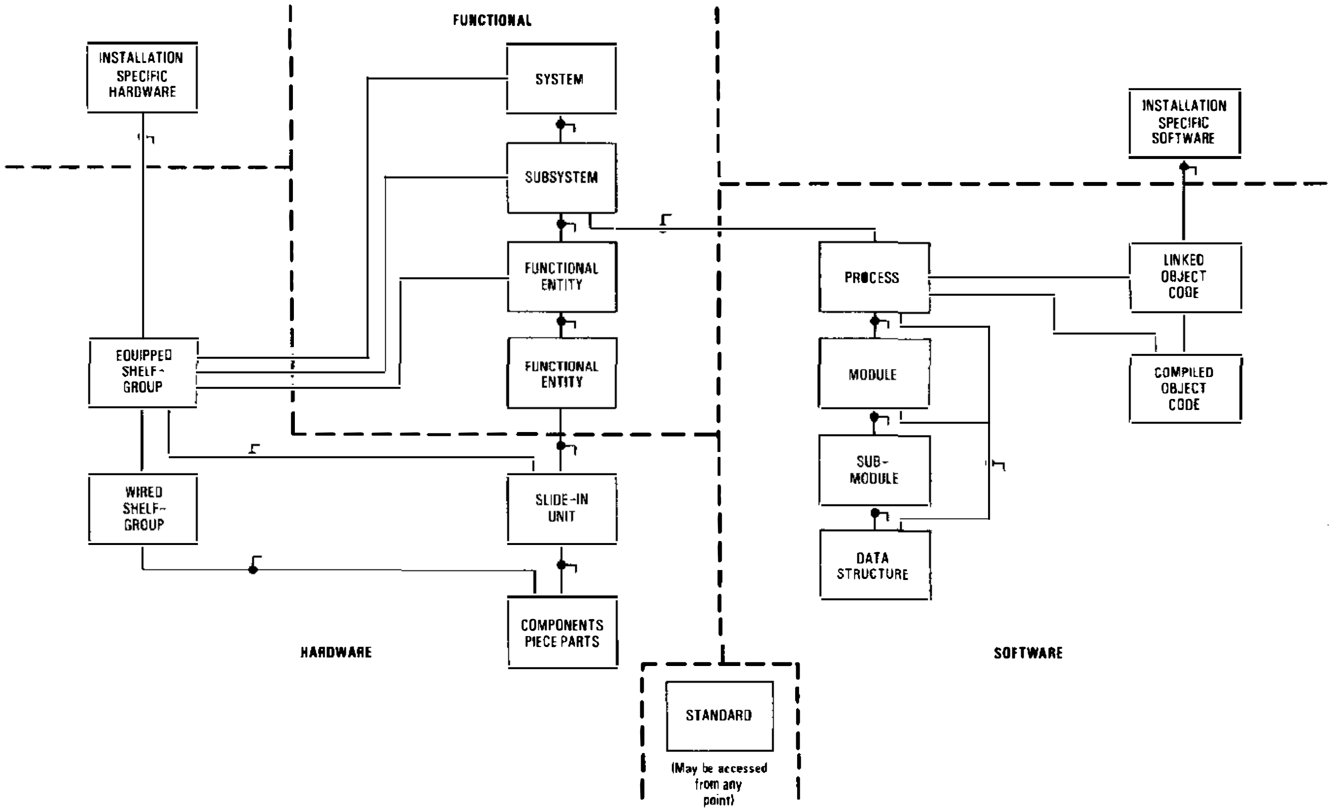


FIG. 3—Hierarchical structure of System X documentation scheme

Two significant factors result from the adoption of the structure shown in Fig. 3:

(*a*) Nodes in the functional hierarchy do not have to correspond directly to realizable items, and thus the basic system structure identified in the functional hierarchy need not change as a result of changes in technology. For example, if a function which originally occupied a complete shelf is subsequently implemented as 2 slide-in-units, there is no need to change the majority of the functional hierarchy to reflect this change. Similarly, the functional documentation is unaffected by decisions (made for operational reasons) to group together on one shelf-group items which are not closely related functionally.

Clearly there is a need to relate a function to its current implementation, and this is done by using the referencing facility of the database, as mentioned earlier.

(*b*) The combination of specific shelf groups within racks, suites, etc. and exchange-specific software are not coded in the structure shown, but are covered by exchange name documentation (END), which is to be the subject of an article to be published in a later issue of this *Journal*.

DOCUMENT TYPES

To provide information in easily managed units, information for an item is divided into a number of *document types*, each of which contains a specific type of information. Each document type is identified by 2 alpha characters. A number of different document types are usually required to fully document an item, and the particular document types allocated will depend upon the nature of the item. For example, a slide-in-unit would require a very different range of document types from a software module. A list of the more commonly-used document types is shown in Table 1.

To assist further in the identification of information of interest to particular users, the document types are arranged in categories, as follows:

TABLE 1

Document Types

Specification Category	Design Category	Product Category
BA: General description	CA: Design text	EA: Layout diagram
BC: External interface list	CB: Block diagram	EB: Parts list
BD: Message formats	CD: Message sequence chart	EC: Wiring list
BE: Sequential operation	CE: Timing chart	ED: Conductive pattern diagram
BF: Interface specification	CM: Program network diagram	EH: Assembly diagram
	CN: Program flowchart	SC: Source code
	CP: Data description	SK: Linked object code
	CT: Provisioning control document	
	DA: Logic/circuit diagram	
	DD: Keyed text	

Specification Category
The specification category contains information describing an item in *black-box* terms, with no reference to its internal structure.

Design Category
The design category contains information describing how an item meets its specification in terms of lower-order items and their interrelation.

Product Category
The product category contains information describing those items that are realized in terms of hardware or software.

Test Category
The test category contains information describing tests appropriate to an item.

It should be noted that, although the use of document types has been discussed in the context of paper documents (or their microfilm equivalent), 2 alpha character document types are also used to identify software and computer-aided-design files[2].

CHANGE CONTROL

A more detailed description of change control is given elsewhere[1] in this issue of the *Journal*. However, the basic aims of the change control procedures are

(*a*) to ensure that those persons who will be affected by a change in design are given the chance to comment on the change and to identify its implication,

(*b*) to ensure that a decision is made by the proper authority who is aware of the full implications, and

(*c*) to record the decision so that all those who need to know of the change are aware of the position.

As the design of an item is recorded in the documentation, changes to design must relate to documentation changes. Two aspects of the documentation scheme which particularly assist the effective operation of change control are

(*a*) the use of categories previously identified, which helps to contain the documentation changes, and

(*b*) the control of documentation by using document lists and compatibility lists, which gives visibility to the documentation impact.

Document lists are produced for each category, and identify, within each category, the compatible issues of documentation. A compatibility list is produced for each node and identifies the issues of the different document lists required for a particular product status; the list also identifies the compatible constituent nodes. It is these links, carried in the compatibility lists, which create the hierarchies described previously.

DOCUMENTATION DATABASE

The database holds all the links which comprise the document lists and compatibility lists and, therefore, provides a commonly available master statement on compatibility. This statement is essential to provide an up-to-date picture of the total information and its inter-relationships. It also provides information which would be difficult to produce by any other means; for example, information on where components are used. A more detailed consideration of this aspect, particularly with respect to its change control support function, is given elsewhere[1] in this issue of the *Journal*.

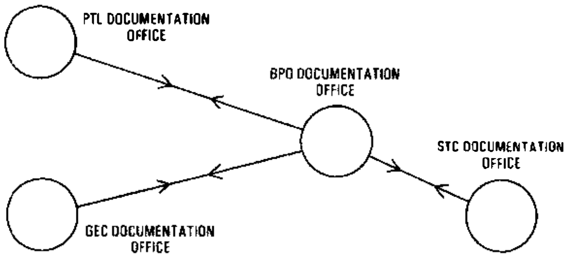


FIG. 4—Basic organization for the interchange of information

INTERCHANGE OF INFORMATION

To ensure that information is made available to all those who need to know, documentation units have been established in each of the firms participating in the System X project. Procedures have been agreed by the participants for the transfer of information as it is produced. The BPO acts as the hub of this information wheel with each company at the periphery. The procedures agreed between the participants cover the use of hard copy (that is, paper, microfilm, etc.) and computer files. The basic arrangements are shown in Fig. 4.

In general, the transfer of computer files will take place through the software master library, which has been described elsewhere[3]. One of the more recently introduced database facilities is the use of a marker to identify the documentation that has been received by the BPO.

CONCLUSION

The design of the System X documentation scheme has been governed by the principle that a comprehensive approach covering every aspect of System X from definition through development, production, installation, maintenance, etc. was, overall, the most efficient. The details have so far only been established in the design and development phase. However, the scheme is now progressively being extended to cover the more operational aspects of System X, and its potential as a comprehensive BPO/Industry standard can be fully assessed.

References

1 SHEEKEY, B., and MILWAY, N. R. P. Change Control and Documentation Database. *POEEJ*, Vol. 73, p. 104, July 1980.
2 HORTH, P. J., and REYNOLDS, R. A. Computer-Aided Design. *POEEJ*, Vol. 72, p. 234, Jan. 1980.
3 COOPER, T. R., and HELLEUR, R. J. System X Software Engineering. *POEEJ*, Vol. 72, p. 240, Jan. 1980.

System X: Design and Support

Part 5—Change Control and the Documentation Database

B. SHEEKEY, C.ENG., M.I.E.R.E., and N. R. P. MILWAY, B.TECH.†

UDC 621. 395. 34: 007

This article outlines the reasons why a comprehensive multilateral change-control scheme and supporting computer database have been developed for the System X project. The article explains some of the more significant operational aspects and facilities of the scheme, including the broad procedural and organizational framework that has been established within the British Post Office and the UK firms who are participating in the development and manufacture of System X exchanges.

INTRODUCTION

Previous articles[1-13] in this *Journal* have described the family of digital telephone exchanges, known collectively as *System X*, and the System X information system[10]. To safeguard the value of the data within the information system, a change-control scheme must be applied. The scheme ensures the integrity of the System X design, and ensures that the engineering and cost trade-off decisions, made on such matters as technical performance, production and operational aspects, are controlled and recorded.

Historically, each of the manufacturers involved in System X has had some form of change-control scheme tied to their production and development activities. The British Post Office (BPO) has a change-control scheme for the procurement of exchange equipment, as reflected in their equipment master-list. However, for System X, these schemes are generally deficient in one or more of the following ways:

(*a*) they are not suitable for computerization,
(*b*) they do not cover software,
(*c*) they cannot deal with high rates of change,
(*d*) they are capable of misinterpretation, or
(*e*) they are not suited to the interchange of information between companies for development, manufacturing and overview purposes.

Therefore, the need was recognized for a comprehensive system that would meet the needs of each of the participants, from the design stages through to the operation of System X exchanges. A task group was established to produce a single scheme to be used by all parties involved in the System X project.

OUTLINE DESCRIPTION OF THE CHANGE-CONTROL SCHEME

The basic functions of the change-control scheme are to ensure that:

(*a*) the proposed changes are appraised by those who will be affected,
(*b*) a decision is taken by the relevant authority cognizant of the implications,
(*c*) the results are recorded so that all parties concerned in the project are aware of the latest position,
(*d*) implementation requirements are established, and
(*e*) compatibility of equipment is maintained.

These functions must take place in a time commensurate with the needs of the user. To achieve these requires a very detailed level of control with suitable support facilities; some of the support facilities are identified later in this article.

A significant problem in assessing the total scale of any proposed change is knowing what other items will require to be changed as a consequence. These changes are known as the *splash and ripple* changes. The identification of potential ripple changes is greatly assisted by the visibility of compatibility provided by the System X documentation scheme[13] and the database.

As far as it is possible, the operation of the change-control scheme is devolved, so that each company can operate its local change-control scheme, but all companies use common forms, procedures and rules. Where a change falls outside the jurisdiction of a particular company, the details of the change are passed to the central multilateral change-control unit, which is operated by the BPO. At present, the BPO local change-control unit and the multilateral unit are integrated but, conceptually, they operate as separate units.

Changes which require multilateral attention are generally those which have impact on work in more than one organization. Examples of such changes are

(*a*) changes to subsystem interfaces, and
(*b*) changes which require modification of operational equipment.

The change-control scheme must be looked at as part of a wider configuration management scheme, which is concerned not only with design and development but with the total impact of changes through to operational equipment. A simplified set of interactions for a change is shown in Fig. 1; the choice of route taken depends on the implications of the change. (The database is shown as being updated only after the decision is made but, in practice, the progress of a change is also recorded.)

CHANGE-CONTROL PROCEDURES

The operation of the change-control scheme is governed by a set of standard forms which identify the information required for

(*a*) requesting authority to make a change (including a description of the change, its implications and the responses of those appraising the request),
(*b*) the update of the database,
(*c*) modification details (covering retrospective changes), and
(*d*) authority for specific implementation (including production and operational aspects where required).

All forms relating to a change will carry a special change

† System X Launch Department, Telecommunications Headquarters

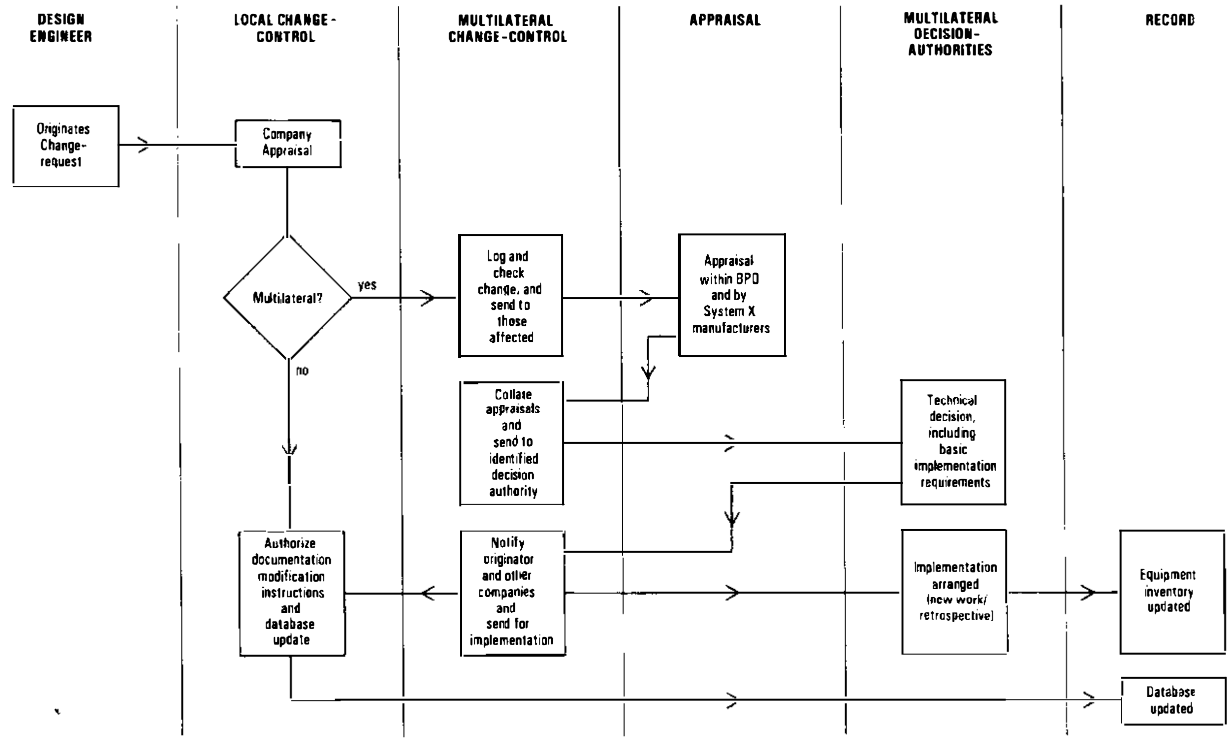


FIG. 1—Outline operation of change-control scheme

number, which is allocated before the change is launched. Related changes are given a linked number.

For a design change which was intended to overcome an operational problem, a simplified sequence would be as follows (see also Fig. 1):

(*a*) A design engineer would originate a change request, which would explain the technical reasons for the change (quoting any fault or defect report identifying the need for the change); engineering details and implications of the change would also be given.

(*b*) The local change-control unit would log the change onto the database and establish a company viewpoint of the change before sending details of the change for multilateral appraisal.

(*c*) Each local change-control unit would distribute on a 'need-to-comment' basis within its own organization. Within the BPO, this distribution would include the operational departments when changes to operational software and equipment are concerned.

(*d*) The appraisals from within the BPO and from the manufacturers would be presented to the decision authority.

(*e*) The answer from the decision authority would be returned, with any explanation which might be required, to the multilateral change-control unit for implementation. The decision would be forwarded to the originator for action, and to the other companies for information and action on any related changes.

(*f*) The originating company would produce the necessary database update and the modification information.

(*g*) The total implementation would be complex where part-installed and in-service exchanges are involved, but a programme covering the total implementation would be produced.

(*h*) The equipment inventory, which records the level of each item of equipment, would be updated as the programme is implemented.

The choice of decision authority would depend on the nature of the specific change and its implications. Thus, in the early stages of the development, where only design considerations apply, the decision authority would be the manufacturer, unless there were wider implications.

At a later stage when equipment is installed in the field, the implementation of retrospective changes will require decisions concerning the expenditure of considerable BPO resources; in such circumstances, the approval of the appropriate BPO authority will be required.

CHANGE-CONTROL RECORDS

There are 3 principal records held on the documentation database for each designed item requiring them. These are

(*a*) the *document list*, which lists the documents recording the design,

(*b*) the *compatibility list*, which identifies the required design level of each of the significant constituent parts, and

(*c*) the *parts list*, which specifies precise quantities of every component.

The history of all changes to each of these 3 records is maintained on the database. This is an important aspect of the change-control scheme because equipment manufacture generally lags behind the latest design level, and because it enables the examination of the records of previously-built equipment so that decisions can be made regarding where retrospective modifications are required.

The database also holds progress information about individual design changes, a register of all design codes issued, and information about document availability from the BPO documentation control office. The principal records and their relationships are shown in Fig. 2.

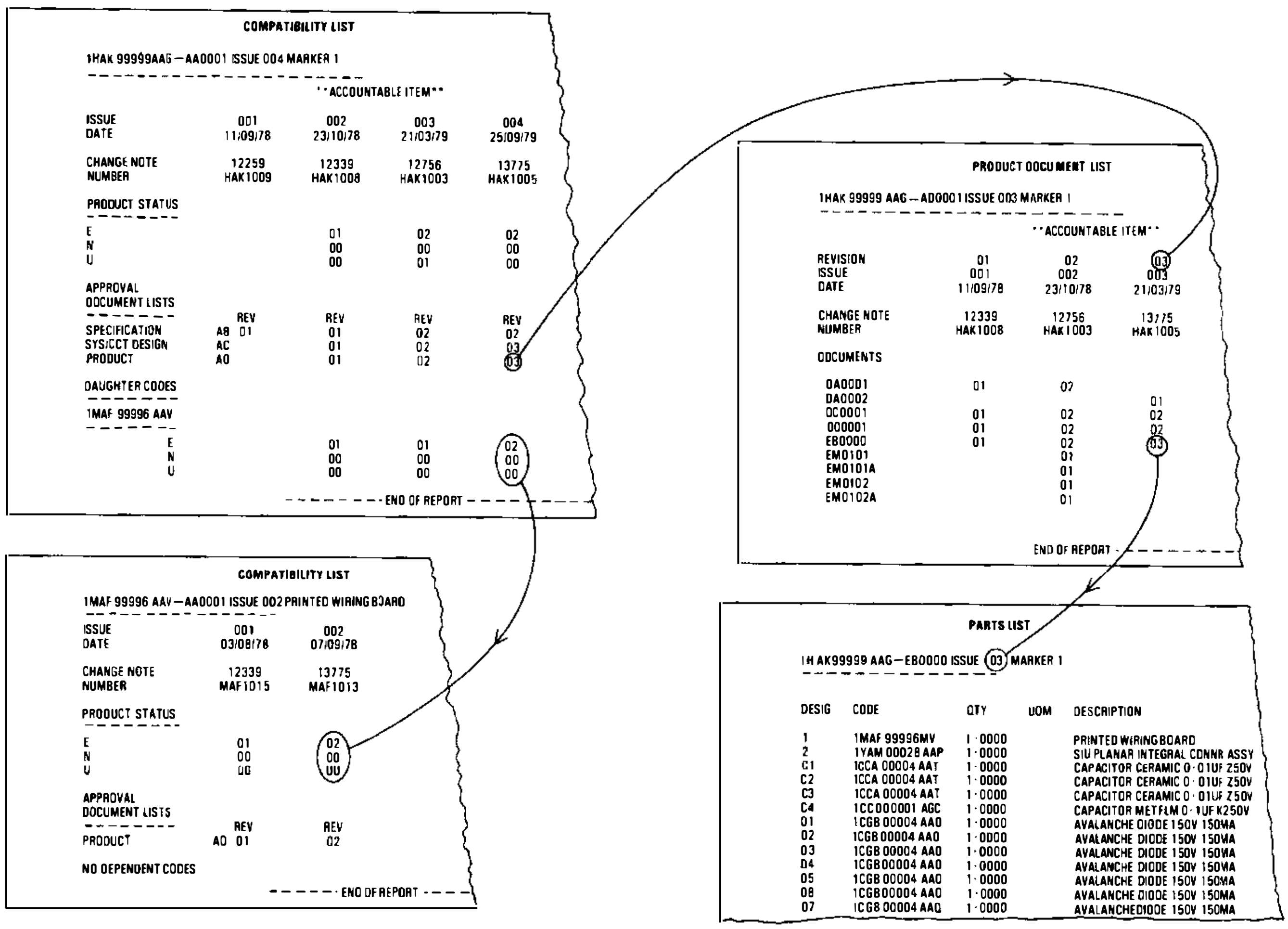


FIG. 2—Extracts from data base records showing compatibility, document and parts lists and their relationship

The Document List

The documents for a given design are grouped into categories. In this way, related information is brought together so that it is easy to see, for each change, aspects of the design which are affected. A separate document list is used for each category.

The documents, identified by their document type and sheet number, are presented in tabulated form. The document type is pre-allocated to each format; for example, a logic/circuit diagram is given the designation DA[13].

Compatible issues of documents are listed in each column. A new column is added to record the new issues when documents are changed. Where the new document issues represent a change of information (that is, more than an editorial change), a new revision number is allocated to the column. Thus, by specifying the revision number, it is possible to identify significant re-issues of the documentation in a given category.

The Compatibility List

Product Status

Changes to a product, as distinct from changes to its documentation, are recorded by means of a *product status*, which appears at the head of each compatibility list column. Although the product and its documentation generally both change together, it is important to note that this is not always the case and either can, in certain circumstances, change independently. Thus, it is necessary to establish clearly whether it is a product or a document that is to be identified and to specify correctly.

Documents are identified by:

COMMON CODE + DOCUMENT TYPE + SHEET NUMBER + ISSUE;

for example, 1HAK 99999 AAG-DA 0001 Issue 001.

Products are identified by:

COMMON CODE + PRODUCT STATUS;

for example, 1HAK 99999 AAG 01 00 00.

The term *product* is used here to refer to manufactured equipment and both source and object software. In the case of manufactured equipment, the product status identification is attached as a label with the common code.

The product status has 3 parts: *E*, *N* and *U*; These descriptions are used to record, respectively, *essential*, *non-essential* and *update* changes, as defined below.

Essential (*E*)

An essential (*E*) change is one that affects the compatibility of an item with other items; a typical application would be to correct a malfunction, or to meet a specification. Similar items carrying different *E* numbers are not interchangeable. Such changes would normally be made retrospectively to all existing products.

Non-essential (*N*)

A non-essential (*N*) change is usually not applied retrospectively; for example, a change to achieve a cost reduction only. Such changes do not affect the compatibility of an item; thus, similar items which have the same *E* number but different *N* numbers are interchangeable.

Update (U)

The update (*U*) part of the product status is a number used to differentiate between items which have achieved a given *E* status by various histories of modification. Thus, 2 slide-in-units, built to a different product status but modified to the same *E/N* status, will have different *U* numbers. This classification is of particular use for identifying the documentation required to support similar items which have been modified differently and those items requiring further modification.

A compatibility list is provided for every common-coded item of information. For each design level, the compatibility list identifies the product status, the revision of each category of documentation, and the design level required for each constituent (or *daughter*) code. Daughter codes may be specified by all or part of the product status or by documentation category revision, depending on circumstances. The compatibility list also identifies certain administrative information; for example, the change-note number and date of authorization.

A new column is added to the compatibility list for each change that occurs; new values are entered in this column for each item of information.

The Parts List

The parts list (document type *EB*) is provided for every item of manufactured equipment (for example slide-in-units, wired and equipped shelf-groups) and shows, for each component, its designation, common code, quantity, unit of measure, description, location, etc.

THE SYSTEM X DOCUMENTATION DATABASE

Multilateral Organization

Change-control records are central to the management of the increasingly computerized systems of design and manufacture, and need therefore to be compatible with them. The BPO needs to control the master reference data (which can change rapidly) and the interchange of data between the companies; the BPO also needs to ensure that the data meets common standards. These basic requirements led to the decision to design a BPO master database, with each manufacturer having a similar, but separately developed, slave database.

The companies concerned use various computer mainframes and different system design and database standards. Therefore, it was extremely difficult to agree the necessary precise specifications that would allow the 4 development teams to work independently and yet produce compatible systems. Testing the ability of the systems to work together and making the necessary amendments has also proved very demanding and time-consuming. A period of over 2 years elapsed between the BPO database becoming available (December 1977) and the last of the manufacturers' systems being fully proven.

Database Update

The database update information is prepared either by data conversion from the change-note forms mentioned previously, or by direct input from a terminal. The information from each company is sent on magnetic tape to the BPO database, and a magnetic tape containing a copy of the added database contents is later returned to each manufacturer's database. The contents of each slave database are compared once a month with the BPO master.

To guarantee that each of the databases contains identical information during a working day requires that the interchange of data is organized to a very tight schedule. Comprehensive checking is carried out at the BPO database during update to ensure strict compliance with multilateral rules. Each company receives detailed error and acceptance reports. The interchange of data between the 4 databases is shown in Fig. 3.

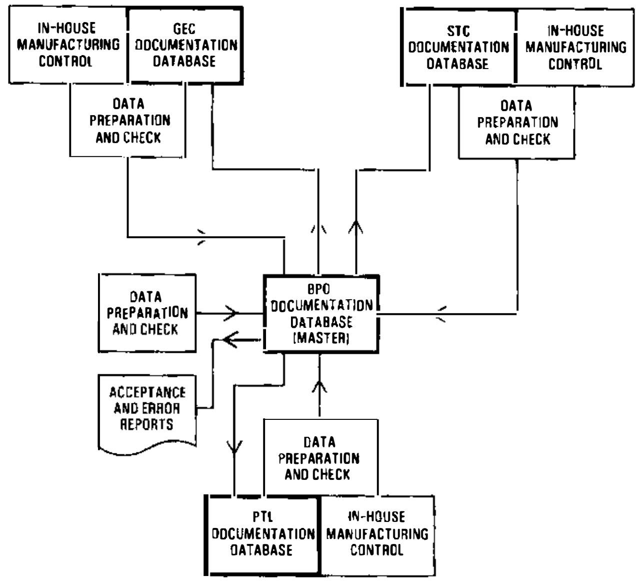


FIG. 3—Database update arrangements

The BPO Database

The initial BPO documentation database came into operation in December 1977 and, because of the delay in fully developing the manufacturers' facilities, was used directly by the other companies up to early-1980. One company had limited in-house facilities, but they were not able to interchange data with the BPO database.

The BPO database runs on an IBM 3033 computer which is programmed in COBOL and uses the IDMS database management system. To date, the database has given very reliable service and has been enhanced several times to add and amend facilities.

Interrogation Facilities

The database information can be provided either to an on-line terminal or as a batch print-out. Information is requested by using remote terminals, and two modes of use are available: the first, for inexperienced users, provides detailed prompts; the second, for experienced users, allows all the necessary information to be input in an abbreviated form without interruption.

The basic database records (that is, compatibility list, document list and parts list) may be obtained either in full or selectively. In addition, derived interrogations are possible, a number of which are described below.

Used On

The used-on interrogation enables the identification of all those codes which are higher in the design hierarchy and which use, directly or indirectly, a specified code. This interrogation is of particular importance in the identification of related changes.

Issue Query

The issue-query interrogation gives the latest issue, product status, documentation-category revisions, outstanding changes, etc. for the code specified.

Related Changes
The related-changes interrogation results in the listing of all the change numbers which have been identified as being related to any specified change number. When implementing a change, this facility helps to ensure that all other changes necessary to maintain compatibility have also been made.

Code Change
The code-changes interrogation results in the listing of all the change numbers allocated against a specified code. The listing may be selected to include all the change numbers allocated, or only those which are still outstanding.

Parts Explosion
The parts-explosion interrogation enables the identification of all the codes (down to the lowest levels) which constitute a specified coded design. For example, the output will list all the functions, racks, shelves, slide-in-units, printed-wiring boards and components required to construct a subsystem.

Regular Outputs

After each update run, the database produces copies of all altered records, either in draft or final form, for checking and archiving. The database also produces a weekly report of all change notes not yet authorized, a monthly register of all common codes allocated and a listing of all changes authorized or rejected during the preceding month.

Future Enhancements

Further enhancements to the database which are currently in development include a status facility and a direct-line-interchange facility, as described below.

Status
The status facility will allow 2 status markers to be recorded against each design level. These are:

(*a*) a *design-acceptability* status, which will be used to indicate the degree of progress with the design of an item, and
(*b*) a *build-release* status, which will be used to indicate the design level or product status that the manufacturers are expected to deliver for BPO supply contracts.

The database will provide comprehensive listings for contractual and ordering purposes. These will be equivalent to the BPO equipment master list used on existing products.

Direct Line Interchange
It is expected that the interchange of data using magnetic tape will be superseded, in the longer term, by the use of direct lines or by a data transmission network. This facility will improve reliability and speed of operation of the change-control scheme.

CONCLUSION

The change-control scheme described in this article has been in use for over 2 years by the 4 firms participating in the System X project and, earlier this year, the last of the 4 documentation databases was brought into service. This period has been used to test and improve the scheme, and to build up gradually the record of System X compatibility as the design progresses into manufacture and operational service. This information will give valuable support to the multi-source manufacture of System X. (By the end of 1979, there was information on some 15 000 coded items of System X design.)

The scheme is not static, for the processes of change control and compatibility recording are planned to be automated; in particular, those for software and for the early design stages.

Although the change-control scheme and supporting computer-database system have been developed for System X use, it has always been envisaged that they will ultimately become a British telecommunications industry standard for all BPO equipment.

ACKNOWLEDGEMENTS

The activity to define and develop the systems described has been very much a joint exercise between the BPO and the System X manufacturers: GEC, STC and PTL. The authors gratefully acknowledge the work performed by their counterparts in these companies. Thanks are also due to the BPO data-processing team who developed the database.

References

1 MARTIN, J. System X. *POEEJ*, Vol. 71, p. 221, Jan. 1979.
2 HARRIS, L. R. F., and DAVIS, E. System X and the Evolving UK Telecommunications Network. *POEEJ*, Vol. 72, p. 2, Apr. 1979.
3 JONES, W. G. T., KIRTLAND, J. P., and MOORE, B. W. Principles of System X. *POEEJ*, Vol. 72, p. 75, July 1979.
4 TIPPLER, J. Architecture of System X. Part 1—An Introduction to the System X Family. *POEEJ*, Vol. 72, p. 138, Oct. 1979.
5 VANNER, N. J. Architecture of System X. Part 2—The Digital Trunk Exchange. *POEEJ*, Vol. 72, p. 142, Oct. 1979.
6 OLIVER, G. P. Architecture of System X. Part 3—Local Exchanges. *POEEJ*, Vol. 73, p. 27, Apr. 1980.
7 WALIJI, A. A. Architecture of System X. Part 4—The Local Administration Centre. *POEEJ*, Vol. 73, p. 36, Apr. 1980.
8 COOPER, T. R., and HELLEUR, R. J. System X: Software Engineering. *POEEJ*, Vol. 72, p. 240, Jan. 1980.
9 RISBRIDGER, J. N. A. System X: Subsystems. Part 1—The Digital Switching Subsystem. *POEEJ*, Vol. 73, p. 19, Apr. 1980.
10 ALLEN, D., and PRICE, C. D. E. System X: Design and Support. Part 1— Information System. *POEEJ*, Vol. 72, p. 229, Jan. 1980.
11 HORTH, P. J., and REYNOLDS, R. A. System X: Design and Support. Part 2—Computer-Aided Design. *POEEJ*, Vol. 72, p. 234, Jan. 1980.
12 LOOME, S. R. System X: Design and Support. Part 3—Software Development Facilities. *POEEJ*, Vol. 73, p. 47, Apr. 1980.
13 SHEEKEY, B., and COLLIER, Q. System X: Design and Support. Part 4—Development Documentation Scheme. *POEEJ*, Vol. 73, p. 100, July 1980.

Determining the End-to-End Grade of Service in a Network—Some New Results

C. HARVEY, B.SC., C.ENG., M.I.E.E.†

UDC 621.395.74: 621.395.31

In the British Post Office, individual routes are provided to specific design grades of service, with little idea of what this actually means in terms of the service a customer receives. This article presents some new results relating the end-to-end grade of service to the individual route grades of service. With this new information, it is possible to gain a better understanding of networks; thereby overall network planning problems, such as grade of service apportionment and overall network dimensioning, can be examined from a slightly more informed viewpoint than has previously been possible.

INTRODUCTION

Determining the relationship between the end-to-end grade of service experienced by a traffic stream in a circuit-switched network and the grades of service on the individual routes used is a fundamental problem in teletraffic theory. No satisfactory method of calculating grades of service exactly has yet been devised, except for the very smallest networks. This is because the exact analytic expressions for the grades of service require a large amount of computation for their evaluation, particularly for networks of any significant size.

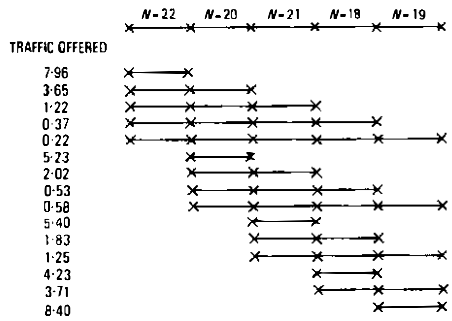
However, recent advances in computational techniques[1] have made it possible to produce limited, but hitherto unobtainable, solutions to the routes-in-series problem (often termed *links-in-series*). With these new techniques, numerical information has been produced to relate individual route grades of service to the end-to-end grade of service. This article discusses and analyses this information, and commences with an examination of the networks represented by a routes-in-series model and the fundamental relationships between the congestion functions that can be used. Selected results for 5 routes in series are presented, with a detailed discussion of their application to, and interpretation of, more general situations. The information is then used to design a forecast network to a given end-to-end grade of service, and also to determine the end-to-end grade of service in a given network. This is achieved with the aid of design charts, which can be used in such network design and analysis.

The article concludes with a brief examination of the effect of the practical environment on the results.

The problems are by no means all solved and many teletraffic problems remain, but it should be possible to design networks with a better idea of the service being provided to customers. Thus, the enigma of relating the design-date route grades of service to the achieved overall grade of service, and rules for grade of service apportionment, can be re-examined from a more informed theoretical point of view than has previously been possible.

TRAFFIC MODELS

The traffic model used assumes the usual simplifying assumptions about the nature of telephone traffic; that is, Poisson arrival patterns, negative-exponential holding times, statistically stable conditions, no repeat attempts, and lost calls having zero holding time. It is also necessary to assume full availability between adjacent switching stages. Hence, the modelled network comprises a number of full-availability groups, interconnected in some way, and offered simultaneous random traffic streams between any pair of nodes.



TRAFFIC POTENTIAL	13·42	13·82	13·42	12·72	14·16
TRAFFIC CARRIED	13·15	13·34	12·93	12·02	13·36
GRADE OF SERVICE FROM TRAFFIC POTENTIAL	0·0086	0·028	0·014	0·038	0·047
GRADE OF SERVICE FROM TRAFFIC CARRIED	0·0072	0·0259	0·0117	0·0329	0·0438

N = Number of circuits

FIG. 1—Example of a traffic matrix

Fig. 1 shows an example of a 5-route network, which indicates that there are 15 interacting traffic streams. The traffic offered to each stream is assumed to be random (that is, fresh traffic) and is, therefore, unsmoothed. Consequently, the numerical results obtained do not take into account any effect on the grade of service that might occur if traffic incoming to the route is non-random; for example, networks using automatic alternative routing.

The model described above should give good results on non-hierarchical routes, but the differences observed between design-date and achieved overall grades of service will probably be greater on hierarchical routes. The numerical results for grades of service are likely to be pessimistic, that is, worse than might occur in a practical hierarchical network. It should be noted that only the relationship between the design grades of service for each route and the end-to-end grade of service is being studied. In pratical terms, this means that a network is being investigated at a particular time, and not over a long period during which the traffic may change or additional circuits may be provided. Hence, any departures from design resulting from forecasting errors, equipment faults and failures, augmentation procedures, delays, and malpractices are not considered in this article.

† Systems Evolution and Standards Department, Telecommunications Headquarters

GRADE OF SERVICE DEFINITIONS

To avoid confusion, some of the terms used in the subsequent part of this article are defined below.

Congestion Functions

A *grade of service* is most generally defined as any practical interpretation of a congestion function. In a lost-call-cleared system, there are two congestion functions that are commonly used: *time congestion* and *call congestion.* Additionally, the grade of service can be estimated from the traffic carried by using Erlang's formula for a full-availability group. These three functions have the same expected numerical value for a full-availability group offered random traffic from a large number of sources.

Similarly, the overall or end-to-end grade of service in the routes-in-series model will have the same expected value for call and time congestion, although they may differ on the individual routes. Unfortunately, there are computational difficulties in determining the call congestion function; consequently, the study has been confined to examining the time congestion for individual routes, the grade of service for individual routes estimated from the traffic carried, and the time and call congestion for the overall route. These are referred to as the *route time congestion*, the *route grade of service estimate*, and the *overall grade of service*.

Summation of Grades of Service

A major part of this article deals with a comparison of the actual overall grade of service of a number of routes in series and the summation of the grades of service of the individual constituent routes. There are two forms of summation that can be used. The *probabilistic summation* is the more accurate form of summation, which should relate the overall grade of service to the route time congestions fairly closely, provided the interdependence between stages is reasonably low.

This can be expressed as follows:

$$B\text{overall} = 1 - (1 - B_1)(1 - B_2)(1 - B_3)\ldots(1 - B_m),$$

where B is the grade of service.

In situations where the blocking is small, the above summation can be approximated to by the *arithmetic addition*, which can be expressed as

$$B\text{ overall} = B_1 + B_2 + B_3 + \ldots B_m.$$

Obviously, these two approximations are easy to compute and are therefore attractive.

PRESENTATION OF NUMERICAL RESULTS

For the routes-in-series model, the following parameters are variables:

(*a*) the number of routes in series,

(*b*) the number of circuits provided on each route,

(*c*) the designed objective grade of service for each route, and

(*d*) the traffic matrix.

These variables can be obtained to produce a vast number of possible situations for study and only a few of them will be examined in detail.

Results of Symmetrical Situations

Results for some simplified situations are presented in Fig. 2, which shows the variation in overall grade of service against the percentage end-to-end traffic for 5 routes in series. In each of the three cases shown, all routes are carrying the same traffic and are dimensioned to identical grades of service. It follows, therefore, that each route contains the same number of circuits.

The upper boundary of each envelope represents the situation where all traffic besides the 5-link traffic is single

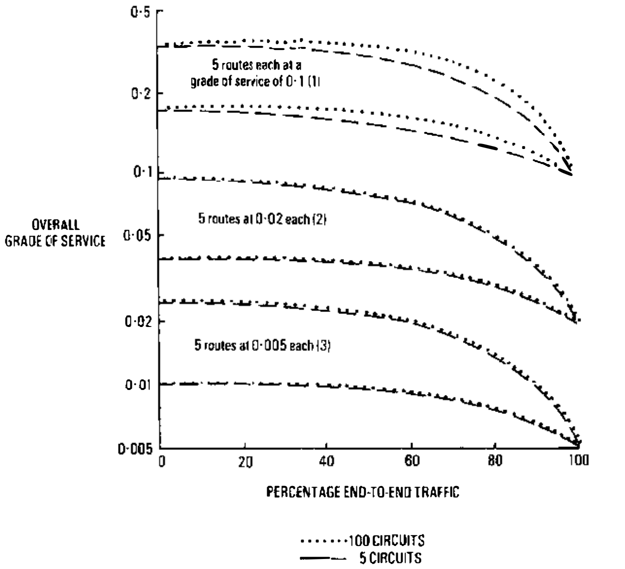
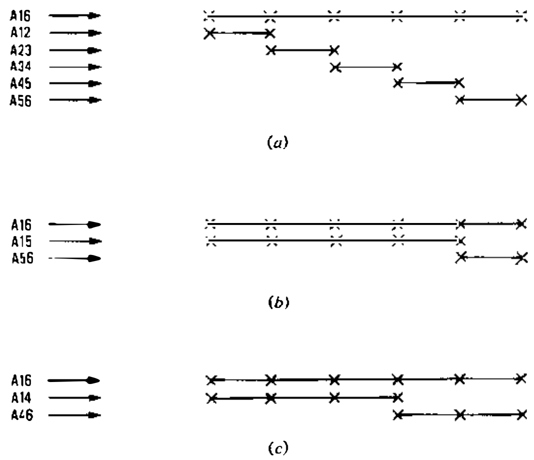


FIG. 2—Overall grade of service/percentage end-to-end traffic characteristics



(*a*) All other traffic on one route (upper boundary on Fig. 2)
(*b*) All other traffic on one or four routes (lower boundary on Fig. 2)
(*c*) All other traffic on two or three routes (lower boundary on Fig. 2)

FIG. 3—Traffic matrices for five routes in series

link traffic (see Fig. 3(*a*)); the lower boundary represents the situation where all traffic besides the 5-link traffic flows over either one and four routes (see Fig. 3(*b*)), or two and three routes (see Fig. 3(*c*)). These are the limiting cases.

The networks studied consist of either 5 routes of 100 circuits or 5 routes of 5 circuits, and the traffic carried was arranged to be such that the route grade of service estimates were exactly the design grades of service. (In practice, the provisioned grade of service is numerically less than or equal to its target for a fixed traffic value).

For these hypothetical and symmetrical situations, the following four observations can be made:

(*a*) The number of circuits per route appears to make little difference to the overall grade of service, unless it is very poor.

(*b*) The numerical value of the overall grade of service reduces as the proportion of end-to-end traffic increases. With 50% end-to-end traffic, the overall grade of service is approximately 75% of the value with no through traffic.

(*c*) In practice, each route might be carrying a mixture of 1, 2, 3, 4, 5-link traffic. Thus, the actual overall grade of service could lie anywhere in the envelope.

(*d*) The arithmetic addition of the design grades of service gives a good approximation to the overall grade of service only when the following conditions exist:

(*i*) the traffic on each route is mostly one-link traffic,

(*ii*) the overall grade of service has a value of 0·1 or less, and

(*iii*) the end-to-end traffic on each route is a reasonably low proportion of the total.

When the overall grade of service has a value greater than 0·1, the probabilistic summation gives a good approximation provided conditions (*d*)(*i*) and (*iii*) are met.

The probabilistic summation of route time congestions for 5 routes, each dimensioned to a grade of service of 0·02, is shown in Fig. 4. While from (*d*) above, there is little difference between the probabilistic summation and the arithmetic addition in this example, the following two further observations can be made:

(*e*) Probabilistic summation of time congestions generally gives a good estimate of the actual overall grade of service, particularly for large circuit quantities; for example, with 50% end-to-end traffic, the summation is, at most, 13% higher than the actual overall grade of service for small circuit quantities (5 circuits per route): the difference is negligible for large circuit quantities (100 circuits per route).

(*f*) With very high proportions of through traffic, probabilistic summation of time congestions gives a poor estimate of the overall grade of service, particularly for small circuit quantities. This estimate is, however, better that that obtained by using the arithmetic addition of design grades of service.

Effect of Traffic Matrix

An important area to study is how the traffic matrix affects the overall grade of service. In the symmetrical situation, for a given proportion of through traffic, the overall grade of service can vary by a factor of up to $N/2$, where N is the number of routes in series. This arises because, at the lower bound of the overall grade of service envelope, the traffic not flowing over all N routes flows over one of two non-overlapping routes, as illustrated in Figs. 3(*b*) and 3(*c*).

Any routes-in-series situation has a traffic matrix that produces many streams of traffic (15 in Fig. 1), and the way in which these streams overlap and interact defines the overall grade of service within the envelope of Fig. 2. This is virtually impossible to evaluate, but a useful insight can be gained by studying the approximate relationship between the overall grade of service and the mean percentage through traffic at each stage.

Fig. 5 shows the ratio between the overall grade of service and the sum of design grades of service plotted against the mean percentage through traffic at each stage.† Note that, for say 40% through traffic at each stage, the 5-link traffic could be any figure from 0 to 40% of the total. Hence, the horizontal scale of Fig. 5 has no direct transform to the percentage end-to-end traffic shown in Fig. 2.

The non-overlapping situations (see Fig. 3) can be calculated easily and are shown as the dashed (straight) line in Fig. 5. This is a theoretical lower bound since, if any node has no overlapping streams, there will be no through traffic.

Various situations have been computed for interacting or overlapping schemes, and the results (for reasonably good grades of service) are relatively insensitive to route sizes and grades of service. A typical result is shown on Fig. 5 as the solid line. The results indicate that the numerical value of the overall grade of service decreases significantly only when there is a high mean percentage through traffic at each stage. To achieve such a high percentage, there must be a low diversity of traffic at each node; that is, a small number of incoming and outgoing routes.

† The through traffic at each stage is the percentage of traffic on route x that appears on route $x + 1$

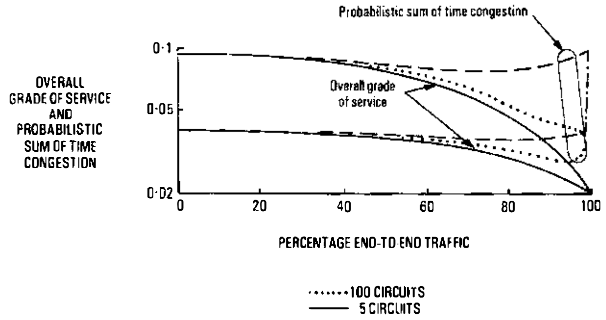


FIG. 4—Probabilistic sum of time congestions

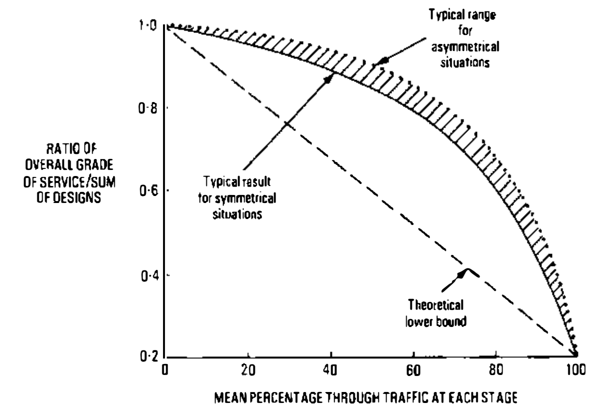


FIG. 5—Typical results

Asymmetrical Situations

The foregoing observations relate to a purely symmetrical situation. Departure from symmetry can occur from varying the number of circuits on each route, or from provisioning each route to a different grade of service. There is therefore a wide range of possibilities that could be studied and it is not practical to attempt a methodical examination of the previous symmetrical observations. If, however, it is postulated that the 6 observations already made apply to any situation, then a number of situations can be sampled and evidence sought that invalidates those observations.

Unfortunately, it is not possible to compare results as in Fig. 2 because the percentage 5-link traffic on each route differs between the various routes, as do the design grades of service. The shaded envelope in Fig. 5 shows the range over which the sampled results have been observed. These samples all had similar traffic matrices to the symmetrical situations. The following additional observations can be made:

(*g*) In asymmetrical situations, summing the design grades of service gives at least as good an estimate as that observed in the symmetrical situations (provided a similar traffic matrix exists).

(*h*) The diversity of results between various degrees of asymmetry is quite small, as indicated by the extent of the shaded area in Fig. 5.

In all, about 40 situations have been studied and no evidence has been found that would cause the hypothesis to be rejected. Hence, one more observation can be made:

(*i*) The observations (*a*) to (*f*) for symmetrical situations appear to apply equally to non-symmetrical cases.

Therefore, for any practical network that can reasonably be represented by a routes-in-series model, it should be possible to apply the general observations and to get a fair estimate of the overall behaviour of the network.

The following section applies this conclusion by producing *design charts*, from which practical examples are compared.

APPLICATION TO NETWORK DESIGN

From Fig. 2 it can be seen that, for the two numerically lower grade of service situations (that is, curves 2 and 3), the general contour of the envelopes is similar. Consequently, a graph can be drawn showing the approximate relationship between the ratio of overall grade of service and the sum of design grades of service plotted against the percentage of end-to-end traffic; this relationship applies for an overall grade of service up to 0·1, and is shown in Fig. 6. Additionally, the envelope of the typical results shown in Fig. 5 can be transformed† into Fig. 6. The following points should be noted:

(*a*) For the upper curve of Fig. 6, the mean percentage end-to-end traffic is equal to mean percentage through traffic at each stage.

(*b*) The typical results for symmetrical and asymmetrical interacting streams have a non-linear transform between the mean percentage through traffic at each stage and the end-to-end traffic.

(*c*) The lower curve is for a mean through traffic at each stage of at least 75%.

(*d*) These results apply only to 5 routes in series.

(*e*) For poorer grades of service, the probabilistic summation should be used in preference to the arithmetic addition.

Graphs like that in Fig. 6 could be used as network design charts to improve the estimate of overall performance obtained by summing the design grades of service. The typical contour would be the best estimate obtainable, unless some further information is known about the traffic matrix. The shorter the routings (for example, Fig. 3(*a*)), the nearer to the upper curve the grade of service would lie; the longer the routings (for example, Fig. 3(*b*) and 3(*c*), the nearer to the lower curve the grade of service would lie.

From Figs. 5 and 6, charts can be drawn to show the region in which the overall grade of service should lie for a given mean percentage through traffic. Typical curves are shown in Fig. 7 (40% through traffic) and Fig. 8 (67% through traffic). These charts are particularly useful because they not only produce bounds for the overall grade of service, but also give an indication of the variability introduced by the traffic matrix. As with Fig. 6, the result tends towards the upper bound for short non-overlapping routings, and to the lower bound for long and irregular non-overlapping routings.

In most practical telephone networks, there is diverse routing and the mean percentage through traffic at each node is probably well under 40%. Therefore, most practical situations can be expected to have little sensitivity to the traffic matrix. However, this may not always be the case and network planners should be aware of the potential problems.

† The transformation is not linear and Fig. 6 should be examined with some caution since it is actually 3-dimensional

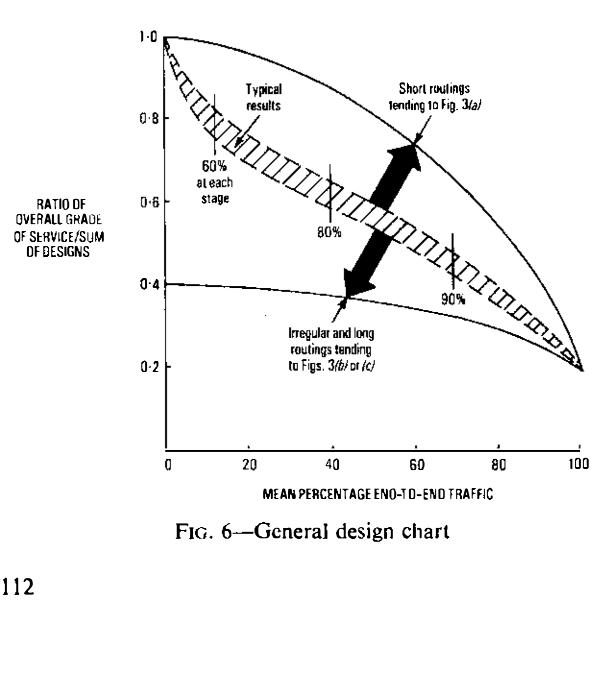


FIG. 6—General design chart

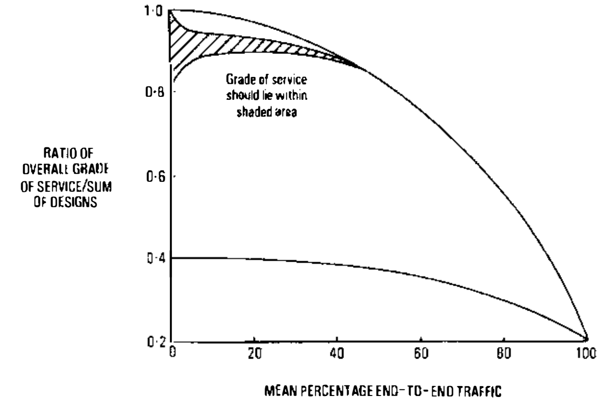


FIG. 7—Design chart for 40% mean through traffic at each node

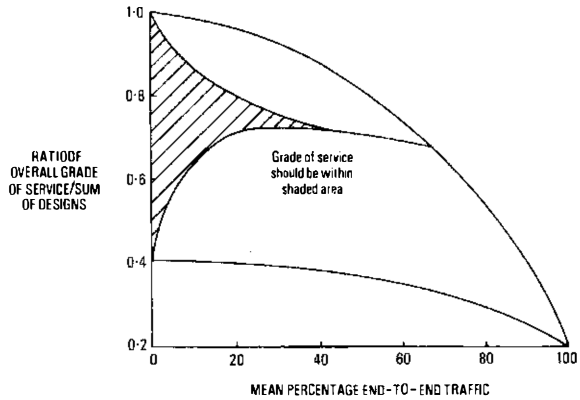


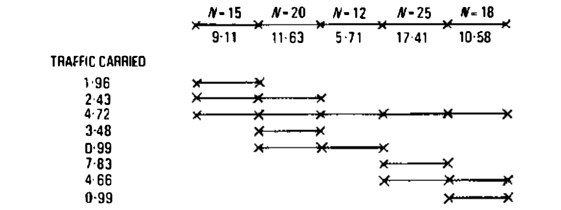
FIG. 8—Design chart for 67% mean through traffic at each node

Example for Network Analysis

Assume that the traffic carried by each route is known because, either traffic records have been taken, or it has been accepted that the design traffic has been achieved. Fig. 9 shows a hypothetical situation, which could be interpreted practically as a Strowger trunking or the interconnexion of a number of exchanges. If the only information about the network is the traffic on each route, all that can be done is to add the grade of service estimates. If the traffic flowing over all 5 routes is known, an approximate figure for the mean percentage end-to-end traffic can be calculated by averaging the percentage figures on each route. A better estimate can then be obtained from Fig. 6 and by assuming a reasonable mix of overlapping streams. If the full traffic matrix is known, an approximate figure for the mean percentage through traffic at each stage can be calculated by averaging the figures for each stage. Referring to Fig. 6, or preferably an appropriate chart similar to Figs. 7 and 8, the overall grade of service can be approximately located.

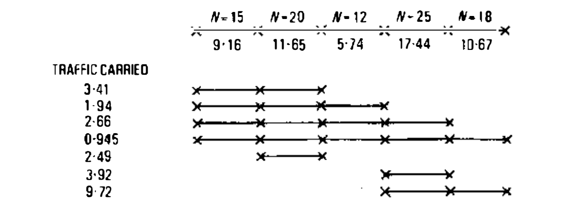
Fig. 9(*a*) shows a traffic matrix where the mean end-to-end traffic is around 50%, and the mean at each stage is around 67%. Referring to Fig. 8, for these conditions, the overall grade of service can be expected to be 0·72 of the arithmetic sum of designs, giving a grade of service of 0·055. A grade of service of 0·056 has been calculated by using the computational method discussed in reference 1.

Fig. 9(*b*) shows the same network, but with the mean end-to-end traffic around 10% and the mean at each stage around 69%. Referring to Fig. 8, there will be little difference between 69% and 67% and the multiplying ratio lies in the region 0·65–0·87. However, the routings are longer and more



						MEAN
PERCENTAGE OF END-TO-END TRAFFIC	52	41	83	28	45	50%
PERCENTAGE THROUGH TRAFFIC	79	50	83	55		67%
GRADE OF SERVICE ESTIMATE	0·025	0·008	0·009	0·023	0·012	SUM 0·077

(*a*)



						MEAN
PERCENTAGE OF END-TO-END TRAFFIC	10·5	8·3	16·7	5·5	9·1	10%
PERCENTAGE THROUGH TRAFFIC	100	50	67	61		69%
GRADE OF SERVICE ESTIMATE	0·026	0·006	0·009	0·024	0·013	SUM 0·080

(*b*)

N = Number of circuits

FIG. 9—Examples of 5-link routes with traffic matrices

irregular than in Fig. 9(*a*) and so the probable value is in the lower region; say, 0·7 of the sum. This gives an overall grade of service 0·056. Using the computational method, gives a grade of service of 0·055.

These two examples illustrate the use of the design charts in estimating the overall grade of service from information known about the network.

Designing from Forecast Traffic

Assume now that the forecast traffic on each route is known and it is required to determine one of the following:

(*a*) the end-to-end performance for given dimensioning rules for each route, or

(*b*) the apportioning rules to be adopted for a given objective end-to-end performance.

In each case, the whole design is based on traffic quantities that are forecast and not measured. Usually, when forecasting, it is assumed that the traffic offered is equal to the traffic carried. However, when designing a network, the forecast traffic is considered to be the *traffic potential* on each route; that is, the traffic that would be carried on a loss-free network. For any route, the traffic potential is greater than the traffic offered because of the traffic lost at succeeding or preceding stages of switching. (Calls lost at succeeding stages would be counted as call attempts, but would contribute little to the traffic.) There is no simple way of relating a forecast or a potential traffic matrix to the carried traffic matrix, and iterative methods would have to be adopted to avoid possible overprovision in the design network.

As a first approximation, it can be assumed that, on any route, traffic potential, traffic offered, and traffic carried are all equal. Provided the number of routes in series is reasonably small, and all the routes are dimensioned to a good grade of service, the approximation is probably reasonable. The design charts can then be used to determine the overall grade of service. This would permit the initial dimensioning of routes according to the objective design rules.

If a better result is required, the analysis must be repeated iteratively to minimize the size of every route. However, it may not be possible to achieve the exact design grade of service on a route because circuits can be provided only in integral quantities; that is, a minimum of one. Consequently, there will be some unavoidable difference between achieved grade of service estimates and the design grades of service.

As an example of network design, consider the network shown in Fig. 1. The forecast traffic offered can be added for each route to produce the traffic potential. An examination of the traffic matrix gives a mean through traffic at each stage of around 40% and mean end-to-end traffic of around 2·5%. Reference to Fig. 7 indicates that, for these conditions, the end-to-end grade of service should lie between 0·87–0·95 of the sum of designs; say 0·91, as there is a good mix of overlapping routings.

If the route grade of service estimates are obtained from the traffic potential, arithmetic addition yields a value of 0·136; the expected overall grade of service would then be $0·91 \times 0·136 = 0·124$. Using the traffic carried gives an overall grade of service of $0·91 \times 0·122 = 0·111$. The computational method gives an overall grade of service of 0·107.

EFFECTS OF THE PRACTICAL ENVIRONMENT

The remainder of this article is devoted to a cursory examination of the various practical considerations that could have an effect on any conclusions drawn from the previous sections.

Variability of Measurements

It has been assumed in the previous discussion that traffic carried on a route is known exactly. In practice, only an estimate of the mean traffic will have been determined from traffic measurements. The sampling variance of measured traffic for a 100-scan sample (for example, 3 min scans over 1 h for 5 d) will have a variance/mean ratio of approximately 0·02. On a route of 20 circuits carrying 12 erlangs, the traffic estimate obtained from this sample will be in the range 11–13 erlangs, giving a grade of service estimate of 0·005–0·018. Errors of this order could obscure some of the effects of routes in series.

Similar arguments apply to forecast traffic, based on measurements, which will, in addition, be subject to a forecasting error.

Design Periods

When analysing a particular situation, the traffic measurements relate to the time at which they are taken, and any conclusions apply only to that time. In practice, a route grade of service builds up to its design value over a long period, and any comparison with the forecast design value, rather than with that existing is likely to prove misleading. It can be assumed that, for the greater part of its design period, a circuit group carries traffic at a grade of service that is effectively zero. Hence, when analysing many practical situations, the network could effectively be "collapsed" (for calculation purposes), such that there are fewer routes in series and smaller proportions of through traffic.

Traffic Models

Throughout this article, a classical model for the traffic has been assumed. This is the model on which all current British Post Office dimensioning philosophies are based. However, there is little doubt that such phenomena as day-to-day variation and repeat attempts exist, and that they can have a significant effect on the performance of the network.

Similarly, the variation of the grade of service throughout the day depends on the daily profile of the traffic offered to each stage of switching. The resulting end-to-end behaviour of a number of routes in series is affected by the relationship between the individual daily profiles and, in particular, by the occurrence of non-coincident busy hours.

The development of suitable traffic models is therefore of the utmost importance to any study of overall grade of service.

Hierarchical Networks

The routes-in-series model is limited to situations where the traffic entering the route of interest is assumed to be fresh random traffic, and where, on leaving, it suffers no further loss. In a practical environment, the traffic often enters the route after it has passed through several stages of switching, and is therefore smoothed. On leaving the routing, traffic is further smoothed by subsequent stages of switching.

The general effect of smoothing is to make the grade of service estimates pessimistic; consequently, an overall grade of service derived from these estimates will also be pessimistic. In the practical environment, therefore, the individual route and the overall grades of service will be less when smoothed traffic is being carried.

Unfortunately, the computational techniques currently available permit only limited networks to be analysed; therefore, it is not possible at present to quantify these effects with any degree of reliability.

Limited Availability

The routes-in-series model assumes that full availability exists at nodes. This can be interpreted as meaning that, in a Strowger trunking, all groups have full availability, or that, in an internal network, the exchanges (or nodes) are effectively non-blocking and losses occur only on the routes. It has not yet been possible to quantify what happens when limited-availability conditions exist, although it is expected that the effect will be minimal.

CONCLUSIONS

This article has presented some new results for network grades of service, and has given an interpretation of their practical significance. Certain network features have been identified from which the error involved in merely adding grades of service can be estimated.

The model is, however, limited in its application and further work is needed to improve upon the model and to quantify its errors.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the major contribution made by his former colleague Mr. C. R. Hills, who developed the mathematical technique[1] from which all the numerical information used in this paper was obtained.

The information given in this article was first published in the proceedings of the 9th International Teletraffic Congress, 1979.

Reference

1 HARVEY, C., and HILLS, C. R. Determining Grades of Service in a Network. Ninth International Teletraffic Congress (1979), Paper 626.

Book Review

An Introduction to Digital Integrated Communications Systems. H. Inose. Peter Peregrinus Ltd., on behalf of the Institution of Electrical Engineers and the University of Tokyo Press. xiv + 342 pp. 342 ills. £15.

The author of this volume, whose pioneering work in digital switching and transmission was internationally recognized before these arts became part of the world's communications systems, is one of Japan's leading researchers in advanced communications technology. The appearance of this book is particularly timely for practising communications engineers now that the integration of these systems is taking place.

The author, after an initial introduction, devotes a chapter each to transmission and switching, moves on to data switching and computer applications, and then to the design of digital switching systems. Although the chapter areas are broad, the treatment of individual topics is at times detailed; for example, 20 pages are devoted to network synchronization. All of the subjects are treated in a comprehensive manner, but the author's background experience has lead him to place emphasis on Japanese and American standards, even though European systems are not neglected.

The chapter on the analysis and design of switching networks starts with an analytical treatment of Poisson. Bernoulli and Erlang statistics, but quickly moves on to apply these statistics to practical switchblock designs and specific systems. Circuit-switched and packet-switched systems are also considered.

The book concludes with a very interesting chapter on future trends. The author has considered 3 main factors: service demand, technology, and constraints. However, he has not, rightly, restricted himself to discussing the technical constraints, but has included social liabilities, regulation and labour issues. Even though these topics have not been covered in any depth, it is refreshing to see them included in a work of this kind.

In a book such as this one, which addresses itself to a swiftly advancing technology, it is inevitable that the treatment of certain topics will have limited currency. Nevertheless, drawing on his own experiences, the author has provided a historical perspective on current ideas that has insight and interest. The book is both a textbook and a reference book, and it should prove useful to all those students and practitioners who are involved in the theory and practice of digital integrated systems.

G. WHITE

Terminating External Cables on Exchange Main Distribution Frames

P. S. BRIDLE, B.SC., and G. R. SMITH, C.ENG., M.I.E.E.†

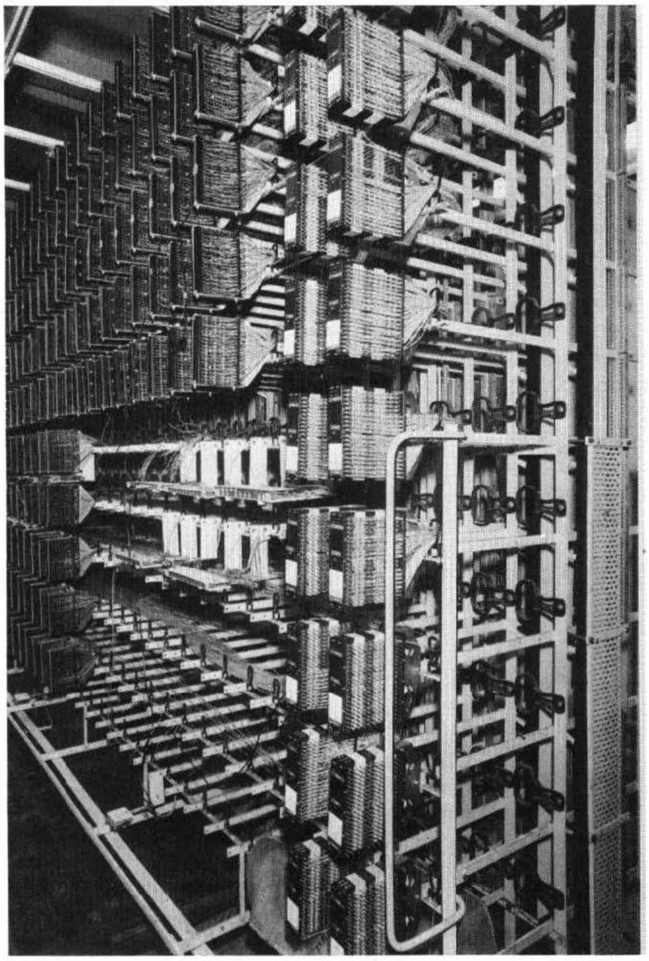
UDC 621.395.657.2 : 621.395.73

Because the main distribution frame (MDF) is one of the largest single items in a telephone exchange, it has been the subject of development work aimed at increasing its capacity, and hence reducing its ultimate physical size. This article describes the evolution of the termination techniques on the line side of the MDF.

INTRODUCTION

External cable pairs from the local distribution network and other telephone exchanges are terminated within the exchange building on the main distribution frame (MDF), which provides an interface between the external and internal cable pairs. Flexibility of interconnexion is achieved by the use of jumper wires between the external cable pairs on the *line side* and the internal cable pairs on the *exchange side* of the MDF. In this way, provision is made for growth on both sides of the MDF to proceed largely independently of each other, according to the influence of the relevant economic and engineering factors.

† External Plant Development Division, Telecommunications Headquarters



Note: Fuse mountings are shown on the left: tests jacks are shown on the right

FIG. 1—Pre-rack type main distribution frame

As the point at which the identity of the conductors change from a cable pair number on the line side to a subscriber's telephone number on the exchange side, the MDF is ideally suited for test access and pair identification purposes. Individual circuits, or groups of circuits, may be tested in either direction. Traditionally, the MDF has also provided the location for various line protection devices which have evolved over the years.

HISTORY

The MDF itself comprises a steel framework, of modular construction in its more recent form, on which are fitted termination units for the internal (exchange side) and external (line side) cables (see Fig. 1). Up to 1975, the majority of external cables were terminated on fuse mountings, the capacity of which has progressively increased while maintaining approximately the same overall size[1]. In 1959, a 40-pair fuse mounting (Type 8064) was introduced which doubled the capacity of the MDF vertical from 200 pairs to 400 pairs. A 50-pair fuse mounting (Type 10064) was introduced in 1972 which, in addition to giving a 25% increase in capacity, had the advantage of numerically matching with the unit construction of external cables. The 50-pair fuse mounting is shown in Fig. 2.

Any further increase in the density of terminations on the MDF was not really feasible until a decision was made on the future use of fuses for protecting external lines. In view of its surge resisting characteristics, the fuse is unsuitable for lightning protection. Also, at electromechanical exchanges,

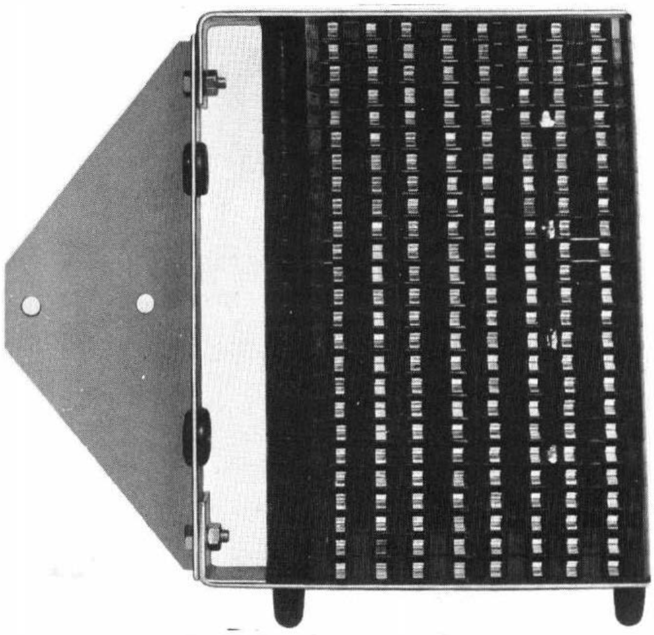


FIG. 2—50-pair fuse mounting

because of the combined impedance of the line and line relay, the fuse is effective only against a contact with the electrical mains supply occuring close to the exchange. With the increased use of polyethylene-sheathed aerial cable and polyvinylchloride (PVC) insulated dropwire, the number of electrical contacts between power lines and telephone lines had reduced, and this downward trend was predicted to continue.

In 1972, therefore, a decision was made to discontinue the protection of external cable pairs with fuses. It was this decision that opened the way for a new design of termination unit for the line side of the MDF.

TEST JACK DEVELOPMENT

In 1973, a value analysis team evolved an external cable termination unit for use with existing MDF construction and practice, at less overall cost per added pair than the fuse mounting. The result was a design known as *Jacks Test No. 37 (JT37)*. Since the facility for fuses was no longer required, a density of 100 pairs was achieved within the approximate overall dimensions of the existing fuse mounting. Test access and disconnexion facilities were retained. External cable and jumpering connexions are located on one side of the unit (see Fig. 3), displaced in separate planes, so that jumpering connexions are accessible and cable pairs are afforded some degree of physical protection. Break jacks are situated on the opposite side of the unit (Fig. 4). The external cable is terminated on the spring of a break jack, the jumper wire on the associated anvil (Figs. 5 and 6). In this way, the line side can be separated, when required, from the internal equipment by using an insulating wedge.

The design allows 1000 pairs to be terminated per vertical on the MDF. An earlier change to a reduced diameter jumper wire served to offset the need to increase jumper ring sizes on the MDF. However, because of the density and recessed position of the line-side tags of the Jacks Test No. 37, a change to wire-wrapped terminations for the external-cable pairs formed a necessary part of the design (Fig. 7).

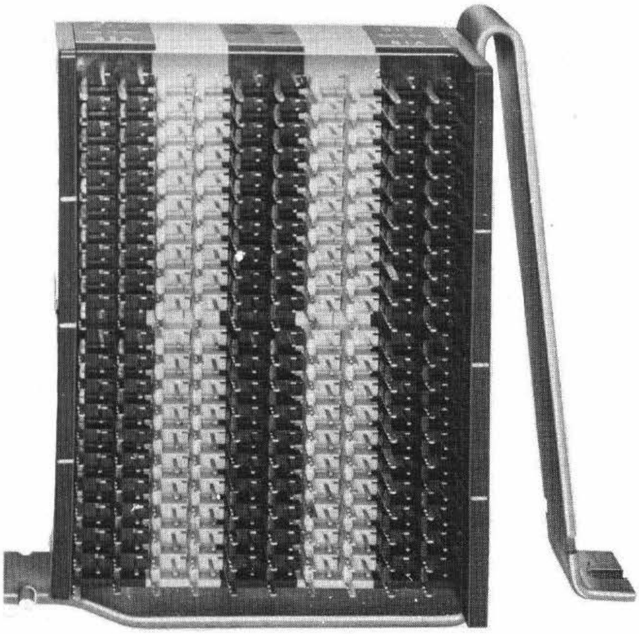


FIG. 3—Jacks Test No. 37 showing termination side

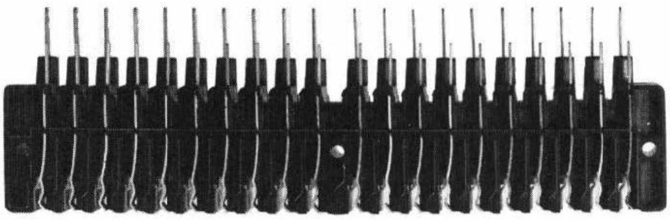


FIG. 5—Construction of Jacks Test No. 37

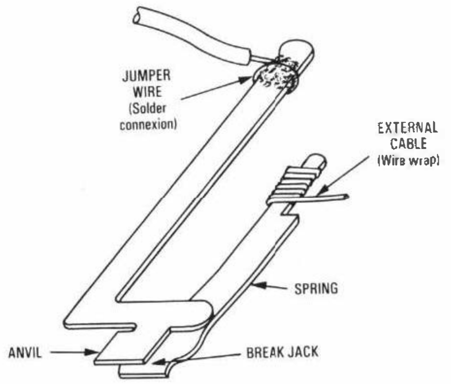


FIG. 6—Principle of Jack Test No. 37 tag

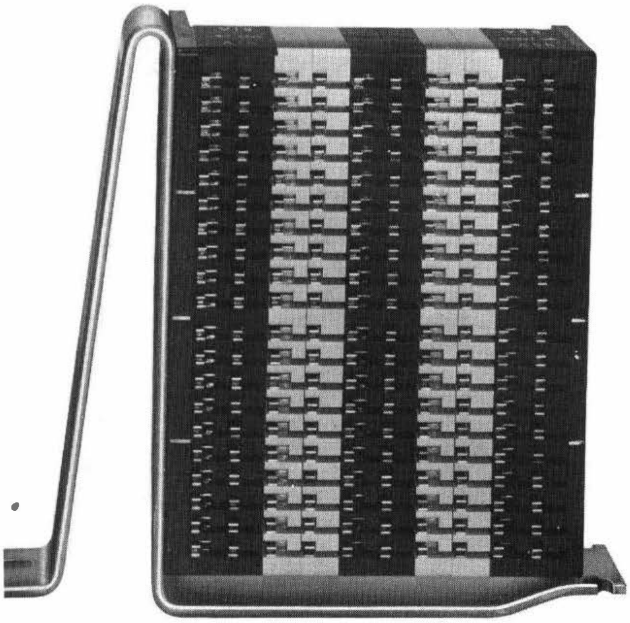


FIG. 4—Jacks Test No. 37 showing break-jack side

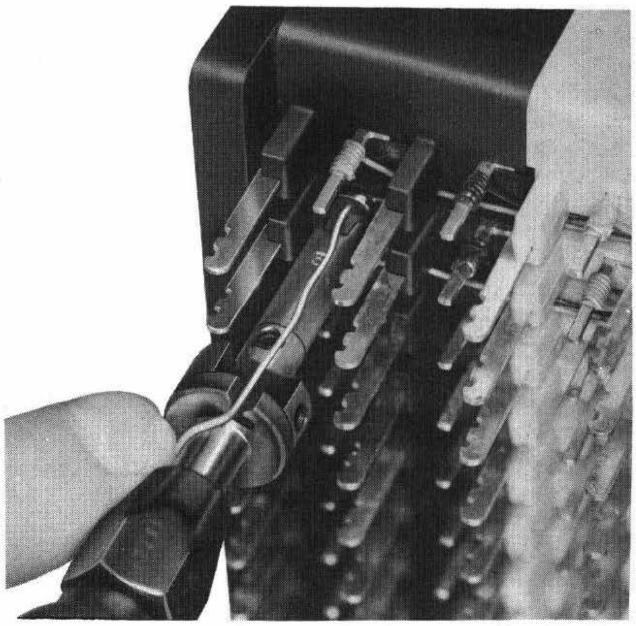


FIG. 7—Wire wrapping external cable on Jacks Test No. 37

WIRE WRAPPING

Wire wrapping has long been accepted in the British Post Office (BPO) as a method of terminating internal cables on equipment racks. Internal cables are generally of one gauge (0·5 mm) of tinned-copper conductors with PVC insulation. The PVC insulation is extruded onto the conductor in a manner which makes it easily removable by the wire-wrapping head during the wrapping process. External cables, unlike those for internal use, may consist of any one of a range of conductor sizes and insulation type. There is also a need for the insulation to be tightly extruded onto the cable conductor during production in order to minimize the leakage of air from the pressurized cable. (The resin air blocks used adjacent to the MDF are generally effective only in preventing the passage of air between the insulated conductors and the cable sheath.)

Together, these difficulties make the conventional design of wire-wrapping head unreliable in attempting to remove the insulation and give an acceptable electrical connexion.

Various types of wire-wrapping head were used in an attempt to remove the insulation prior to wrapping, but with only partial success. A major difficulty was that the axial force required to sever and pull off the insulation often exceeded the breaking strength of the conductor (particularly 0·32 mm diameter conductors). With the increased use of cellular polyethylene insulation, a new approach was considered, whereby the conductors were wrapped without any attempt being made to remove the insulation at the wrapping head (see Fig. 7), the corners of the tag being sufficiently sharp to contact the wire through the insulation. With some initial scepticism about the outcome, a programme of accelerated life testing was commenced, involving climatic cycling, heat ageing, simulated industrial atmosphere and salt-spray exposure. These tests showed that the termination was reliable, and the technique of wrapping insulated copper wire has now been introduced. However, it was during this period that aluminium-alloy-conductor cables were introduced into the local network.

ALUMINIUM-ALLOY CONDUCTORS

The basis of the BPO decision to adopt aluminium alloy as the conductor material for the majority of external local cables has been dealt with in another article[2]. The problems of terminating aluminium conductors are well known and are linked primarily to its stress-relaxation, cold-flow and oxide-formation properties. To establish a good electrical connexion, the oxide film must be removed locally so that the bare metal surface is contacted. At the same time the contact force must be sufficient to exclude air from this junction to prevent any further oxide formation. After the connexion is made, however, the cold-flow properties of the metal allow it to relax from areas of high stress more rapidly than for copper, and hence reduce the contact pressure. Oxide formation may recommence and increased contact resistance results.

Therefore, until a reliable method for terminating aluminium-alloy conductors is developed it is considered expedient to maintain the use of copper conductors, in the form of a tail cable, for exchange termination purposes.

With the foregoing in mind it is worth considering the history of aluminium termination by wire wrapping over the last few years. The initial laboratory work on wire wrapping ¾H-grade aluminium conductors showed promise and culminated, in 1970, when large experimental petroleum-jelly-filled cables having these conductors were directly terminated at Shelford and Corby[1]. Although these terminations proved to be reliable, other reasons[2] brought about a decision to adopt aluminium alloy as the conductor material for future cables. Normal pressurization techniques were adopted for these cables instead of petroleum-jelly filling and this, together with the different mechanical properties of aluminium-alloy conductors, resulted again in problems with the removal of the insulation. Efforts were directed then at preventing wire breakages, which occurred when a conventional wire-wrapping head was used to wrap aluminium-alloy conductors. Since this work was running in parallel with that for wire wrapping copper conductors, there was initial optimism that the wrapping technique evolved for copper conductors, with the insulation not being stripped from the conductor, would be successful for aluminium-alloy conductors. Comparison of electrical resistance measurements of aluminium-alloy wire wraps, made without removal of insulation, that were aged naturally (at ambient temperature) or subjected to accelerated ageing (by climatic cycling), showed that the increase in contact resistance during accelerated ageing was not significantly greater than for similar wraps retained at ambient temperature. The expected time compression in the climatic-cycling cabinet had not materialized and the results of this particular supposed accelerated test were not therefore a reliable indication of long-term performance.

Accelerated Ageing

An accepted approach to accelerated ageing is to use the heat-ageing and industrial-atmosphere tests of the BPO specification for PVC-insulated copper-conductor wire wraps. This test involves maintaining the wire wrap at 125°C for 1000 h. The unstripped polyethylene-insulated copper conductors passed this test, but those with aluminium-alloy conductors were found to age significantly in only 100 h at 125°C. In part, this is because the alloy itself is rapidly aged at these temperatures. It was thus necessary to establish an accelerated-ageing test suitable for the aluminium alloy which would simulate life under normal service conditions.

The basis for heat ageing of a wire wrap, as a means of stress relaxation to degrade the contact, dates back to the original work carried out by Bell Telephone Laboratories[3]. Briefly, when the wire is applied to the terminal the tension in the wire results in a torsional load being applied to the terminal. The helical formation of the wire wrap causes the terminal to twist in the opposite sense to that of the helical rotation of the wire as it is applied to the tag. Over a period of time the stress in the wire relaxes, the terminal returns to its original state and the stored energy in the system falls to zero. At this point, the contact pressure is assumed to be zero but, nevertheless, some electrical contact is likely to be maintained, at least with copper conductors.

The purpose of heat ageing is to raise the temperature and accelerate the relaxation of the termination and the consequent loss of stored energy. Knowing the acceleration factor involved, it is then possible to predict what the stored energy of the system will be after a pre-determined period of time at ambient temperature (in the BPO case, 40 years at 20°C).

In theory, when the stored energy falls below a certain level the gas-tight metal-to-metal joint at the corner of the post is lost and electrical resistance increases. The figure quoted in the early Bell literature is for this to occur at 50% stress relaxation, although this is taken to be a somewhat arbitrary limit. As stated in the work carried out by Ferranti[4], "the widely quoted figure of 50% maximum stress relaxation is rather low and may safely be set at a higher value". In other words, the electrical stability may still be acceptable even when the stress has relaxed to less than 50% of the original. The technique for obtaining quantitative measurements of stress relaxation is to measure the angle of twist in a wire wrap post. To do this on a conventional 7-turn wrap is difficult because of the small angles involved. It is therefore necessary to magnify the angle by wrapping a greater number of turns, (100 has been found to be suitable[3, 4]), on a specially-made long tag. By reading the angle of twist after the wrap is made and during heat ageing, a measure of the relaxation may be obtained. Care must be taken to note any permanent deformation of the tag at the end of the test.

The first operation was to establish what tension in the wire resulted in sufficient notching of the wire without causing it to fracture when unwound from the post. An optimum tension was chosen for insulated wire and uninsulated wire. One-hundred-turn wraps were prepared and the terminal-post twists measured. Work carried out by Research Department resulted in the establishment of a soundly based heat-ageing test for aluminium alloy wire wraps. However, this work confirmed what had been suspected earlier, that insulated aluminium-alloy conductors could not readily be wire wrapped and a technique for removing the insulation had to be developed.

Insulation Removal

The standard design of commercially available *cut, strip and wrap* wire-wrapping head relies on tension being applied to the wire, either at the point the insulation is stripped, or at the shoulder of the wrapping head where the wire changes direction, from being parallel to the axis of the tag to being tangential. The wire is then wound round the tag under tension causing the tag corners to indent the wire and thus achieve the long lasting electrical connexion, the stress being built in as previously explained. Attempting to remove the cellular insulation on aluminium alloy conductors by this technique resulted in the frequent breakage of the wire due to its low tensile strength.

A number of different head designs are being investigated in an attempt to achieve the removal, or partial removal, of the insulation so that terminations that match the reliability of a pre-stripped wire wrap may be obtained.

LIGHTNING PROTECTION

From 1960 until quite recently, lightning protection has not been provided on MDFs. The practice has been to provide pole-top protection on overhead lines having more than 4 spans (250 m). Experience has shown that little damage to Strowger equipment has resulted from this policy. The standard BPO test to simulate lightning surges evolved during this period—a pulse of peak value 4 kV and duration of about 100 μs. Strowger equipment is usually undamaged by such a pulse.

In recent years however it has become apparent that the 1960 protection standard is not adequate for electronic and crossbar exchanges. This equipment can be damaged even by surges that occur on wholly underground lines due to nearby lightning strikes. A new protection standard was therefore introduced in 1978 for electronic and crossbar exchanges. This stipulates protection on the MDF for all lines except those routed entirely through heavily built-up areas such as city centres. This exception is possible because pipes and other metallic plant in the ground serve to screen cables from lightning-induced surges. In future, the specification for exchange equipment is likely to require it to withstand a pulse of 1·5 kV peak, but having the standard shape laid down by CCITT; that is, a duration of about 700 μs.

The use of a gas discharge tube (GDT) has proved to be the most effective method of protection against voltage surges. These tubes contain a low-pressure inert gas between earth and line electrodes. The GDT chosen for this application will operate at 245 V spark voltage, 1 kV impulse voltage, and will restore when the voltage is removed. The three-pole GDT having a common centre electrode also ensures that each leg of the circuit will break down virtually simultaneously, thus reducing the risk of acoustic shock to the customer.

This type of protection is suitable for electronic and crossbar exchanges and efforts were directed to the development of a means of incorporating the GDT protection facility on the MDF. This was achieved by the design of a protector mounting which had the capacity to accommodate 100 three-pole GDTs (Protectors No. 14A) and which could be assembled onto the test jacks, as shown in Fig. 8. Each GDT socket is

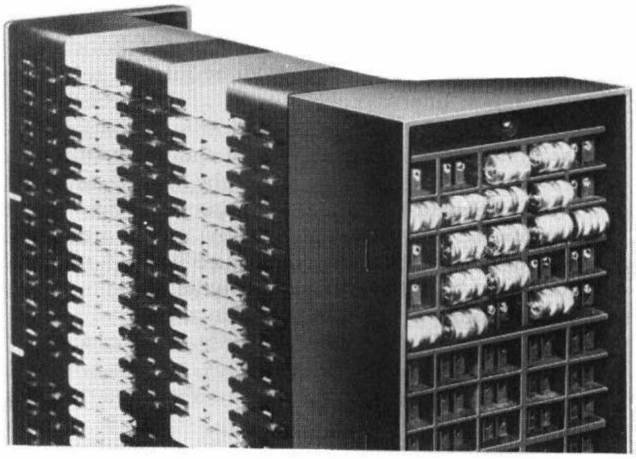


FIG. 8—Jacks Test No. 39 (combined test jacks and protector mounting)

factory wired from the rear of the protector mounting to the base of the appropriate termination tag of the test jack, leaving sufficient length of tag for the permanent wiring. A single earth wire connects the protector mounting to the earth terminal of the MDF. The combined test jacks and protector mounting are known as a *Jacks Test No. 39*. The protector mounting may also be obtained as a separate item which can be fitted to existing test jacks if required. Such retrospective work is, however, difficult in situations where jumper wires exist, since the test jacks must be moved onto a temporary support mounting to allow access for the wire-wrapping gun to terminate the connexions to the protector mounting. In such circumstances the jumper wires may require extending to allow the necessary freedom of movement.

CONCLUSIONS

Present indications are that, given a suitable wrapping head, a wire-wrapped test jack system is acceptable for both copper and aluminium-alloy conductors. However, there is still a need to appraise other recently developed termination techniques. Many of the proprietary systems employ the insulation displacement (slotted tag) principle for wire termination, and have proved successful when used with copper conductors. Their reliability when used to terminate aluminium-alloy conductors is however not fully proven.

Current development work within the BPO suggests that a design of multiple-slotted tag may well overcome the earlier problems encountered with bifurcated tags. It is considered very desirable, however, that any development must be compatible with existing MDF installations, and preferably be capable of being incorporated in the existing test jack design so that costly modifications to existing MDFs are averted, and the 1000-pair vertical is retained.

ACKNOWLEDGEMENTS

A number of groups in the BPO Telecommunication Headquarters have been involved in the developments outlined in this article. The authors wish to acknowledge their assistance and also the many Regional and Area staff who have made a valuable contribution to the field trials.

References

1 HARRIS, R. H., and KILSBY, K. B. Terminating External Cables in Telephone Exchanges. *POEEJ*, Vol. 65, p. 43, Apr. 1972.

2 PRITCHETT, J., and STENSON, D. W. Aluminium Alloy as a Conductor for Local Network Cables. *POEEJ*, Vol. 68, p. 132, Oct. 1975.

3 MCRAE, J. W., MALLINA, R. F., *et al.* Solderless Wrapped Connexions. *Bell Telephone System Monograph 2085*, May 1953.

4 FERRANTI LTD. The Evaluation of D50S Aluminium-Alloy Wire-Wrapped Joints. Sept. 1969.

Traffic Measurement Installations for Collecting Data for Long-Term Traffic Studies

W. DAWSON, and P. J. BURVILLE, B.SC., PH.D., C.ENG., M.I.E.E., F.S.S., M.B.C.S.†

UDC 621.395.31

This article describes installations for collecting traffic data for long-term studies with the object of validating present and possible future traffic models, and developing teletraffic theory for them.

INTRODUCTION

An earlier article* considered various types of telephone traffic and call information required to manage the telephone system, and identified several forces that lead to the automation of data collection. This article describes and discusses a particular traffic study that is being carried out in connexion with research and development activities. A description is given of special equipments used to record the data, which is stored on magnetic cartridges for later transcription to 12·7 mm magnetic tape. This example is a long-term traffic study based on the collection of live traffic data, in which the objective is to evaluate traffic parameters and to determine the validity of various traffic modelling methods. Incidentally, because the standard exchange traffic record can also be produced from this data, it has been possible, in the two exchanges concerned, to dispense with the use of exchange automatic traffic recorders (ATRs).

It is often necessary in these cases to collect as much information as possible about a particular switching stage or traffic situation; in many instances, because of the volumes of information involved, the data collection becomes feasible only if it can be fully automated. The rapid introduction of new technologies into switching systems, permitting new customer services to be offered, creates an urgent need for more information about the basic traffic flow and the overall effect of factors such as introducing new systems, services and tariff structures into the existing national network. The techniques described in this article are those to be used by the British Post Office (BPO) to collect the circuit-group traffic and calls information at two medium-sized non-director exchanges, where the collection equipment is expected to be in operation for 4–5 years.

OBJECTIVES

The data collected is to be used to achieve the following specific objectives:

(*a*) to determine the validity of existing traffic models when used with the present and alternative procedures;

(*b*) to assess the extent of any departures from these models by live traffic;

(*c*) to identify, if necessary, more precise models than those used at present;

(*d*) to develop the teletraffic theory for these models.

There are three distinct separate phases in an overall data-collection exercise:

(*a*) the overall design of the experiment,

(*b*) the actual collection and archiving of the information, and

(*c*) the analysis of the information and the interpretation of the results.

This article deals with the second phase; that is, the collection of the data. As the necessary data was not available from normal sources, a special collection exercise was needed. The chosen elements of the switching network had to

(*a*) provide a reasonably stable source of information so that atypical behaviour was avoided, and

(*b*) cater for typical growth and other pattern changes that could be expected.

As well as the basic information to be collected for a study, it is possible to examine the feasibility of obtaining additional information, at little extra cost, that might otherwise be lost forever. However, care must be taken not to collect data merely because it is readily available if it will not significantly add to the worth of the experiment. In the example described here, the exchange traffic records (A854s) are produced as a by-product.

CHOICE OF SAMPLE

To ensure that the study produced meaningful results, outside influences had to be restricted to those that could occur anywhere, with none that would be peculiar to a particular area; for example, new towns, major switching plant renewals, or re-arrangements during the life of the experiment. Equipment extension programmes had to be accepted as a normal influence during the life of the study. Two switching units were chosen, each being a Strowger non-director exchange; this permitted the seasonal and annual trends to be studied, and also offered the prospect of investigating switching stages in series. The type of traffic-measuring equipment was determined by the traffic and call information required for the experiment. The daily recording periods of 0800–2300 h, Monday to Friday, were considered appropriate so that morning, afternoon and evening busy-hours were included. In addition, information on individual circuit conditions was collected from 0100–0200 h, Monday to Saturday, to enable likely busied-out circuits to be identified. A suitable time-scale to permit valid conclusions to be drawn was fixed as 5 years.

CHOICE OF METHODS

When the exchanges had been chosen, the number of recording points was known, as was the type and size of traffic recorder required for the collection exercise. For a project having a long life, it is very important that continuous support is provided, and this can be done only with local agreement and co-operation. However, instead of allocating special staff at each stage of the study, it was decided that better results would be obtained if the work was directly linked with as many existing duties as possible, such as the exchange service duty and the trunking-and-grading duty. This was mainly to ensure that the measuring exercise was as fully integrated into the normal exchange life as possible, since this leads directly to more background information on the operation of the exchange being available to the research and development personnel.

The data collection equipment fitted in the exchanges had to be flexible enough to allow for growth and to permit

† Dr. Burville was formerly in the System Evaluation and Standards Department and is now in the System X Development Department, both in Telecommunications Headquarters. Mr. Dawson is with the North Eastern Telecommunications Region.

* BURVILLE, P. J., and DAWSON, W. Automation of Traffic Data Collection. *POEEJ*, Vol. 71, p. 164, Oct. 1978.

changes to be made with the minimum interruption in the data flow. The necessary long-term financial and resources commitment had to be fully guaranteed for the life of the study. These commitments included research and development requirements, local support and the necessary computer-processing facilities.

BEHAVIOURAL ASPECTS

It was necessary to decide whether to develop the special measuring equipment required in-house or, alternatively, to purchase a proprietary item. An in-house development would have meant a considerable time lapse before equipment was available, which would probably have affected the choice of exchanges and the initial research already performed in preparation for the study. It was therefore decided to obtain a proprietary item under competitive tender. The final apparatus chosen met most of the desired facilities and the delivery dates were acceptable. Sufficient support for the life of the study and the manufacturer's commissioning and training facilities were also available.

Extensive consultations were held with everyone associated with the normal operation of the subject exchanges to ensure that a workable arrangement could be reached, with the minimum interference to normal maintenance and other duties. All the local staff concerned directly with the project were given adequate training and were made aware of the objectives of the exercise so that the level of commitment necessary for the success of the exercise could be obtained.

To provide the local exchange management with feedback from the measurement exercise, a copy of the traffic records, checked by the remotely-located research and development personnel, was made available. However, it was subsequently found that a direct (unchecked) on-line copy of the exchange records would have been of immense value in faulting and local wiring checking; unfortunately, it was then too late to include the facility in the equipment configuration.

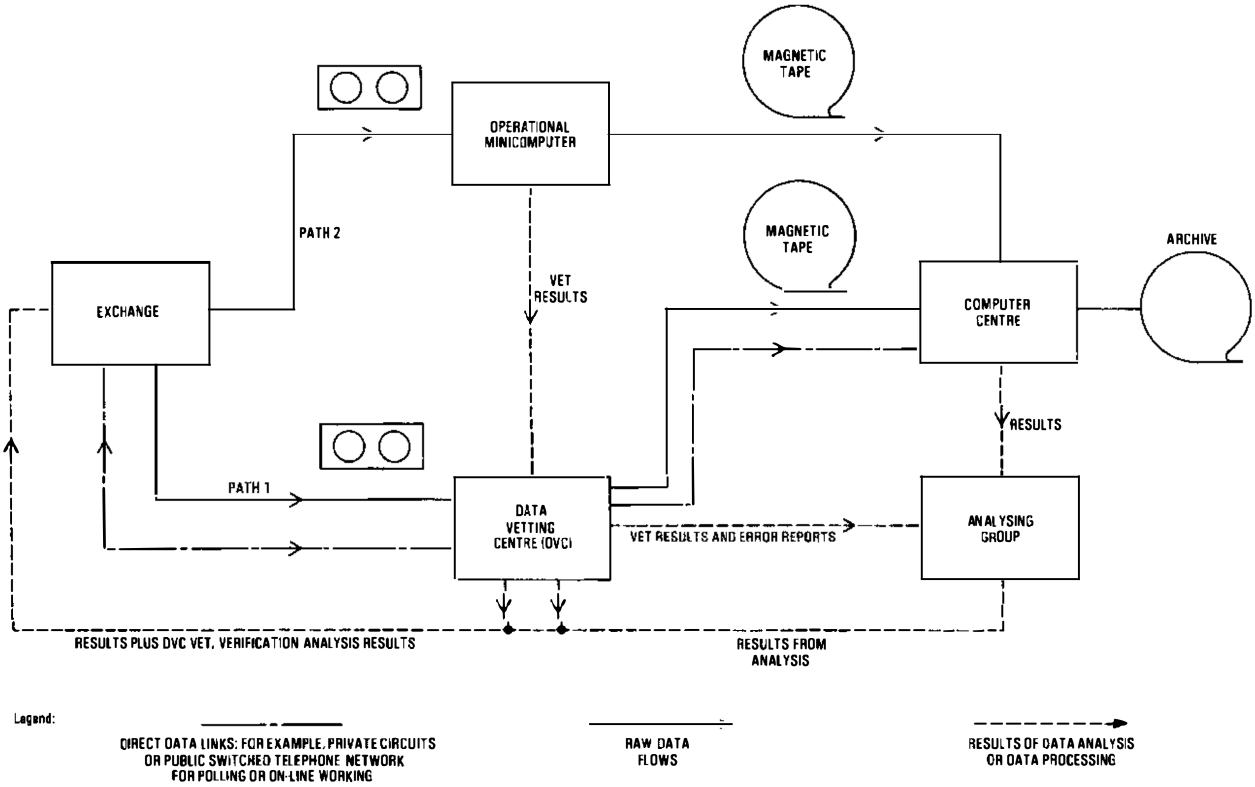
TECHNICAL ASPECTS

The amount of data collected in long-term studies is, of necessity, extremely large, but there is also the urgent need for a quick indication of any fault or other difficulty that corrupts the data. To meet this need, the collected data is checked and transcribed from the magnetic cartridges to 12·7 mm magnetic tapes; at this preliminary stage of analysis, faults and other corruptions of data can be located. However, this delays reports of difficulty reaching the collecting points. An alternative technique could be to have a local hard-copy record at the collecting points, but this is expensive and presents a significant vetting problem because of the large volume of data involved. A further method of dealing more directly with faults and errors is by logging the information over the public switched telephone network (PSTN) or via a private circuit. This procedure has been tried and has proved to have a worthwhile advantage in time saving, but the procedure is still in the development stage.

The initial planning and ultimate cross-connexion patterns adopted between recording equipment and the exchange apparatus have an important influence on fault-finding activities. Although sufficient flexibility is desirable to allow for the expected growth in the number of connexions, this can make the locating of faults in the apparatus slow and difficult.

While the information is being collected, the actual state of the exchange must also be monitored, so that the context of the traffic measurements is completely defined, at least for the exchange structure. Every week a *routing map* of exchange traffic showing the switching trains used for various types of calls must be collected. A grading table, giving the cross-connexion patterns used at each switching stage, is also essential. These additional items are usually recorded on the beginning of the first tape of data collected each week.

Reports of faulty exchange equipment are usually collected daily by recording on individual circuits during periods of light traffic and assuming that every item permanently engaged is busied-out or faulty. Obviously, it has been found that some such circuits are carrying genuine telephone traffic. To supplement the data collected automatically, the local staff maintain a daily diary for recording faults and



Path 1—Data-sampling path   Path 2—Data route for bulk information transfer

FIG. 1—Block diagram of overall recording system

other local events that may give rise to increased or decreased telephone traffic.

THE RECORDING SYSTEM

A brief outline of the overall data collection and storage system is given below, together with a block diagram of the exchange illustrating the location of the connexion points for the monitoring equipment; finally, a block diagram of the monitoring equipment is also given.

Overall System

The information flow for the system is illustrated in Fig. 1, in which the basic data route for bulk information is shown as path 2. From the exchange, the recorded data is sent on a magnetic cartridge to an operational minicomputer, where the data is transcribed to 12·7 mm magnetic tape and transferred to the main-frame computer centre. Before transfer, however, the data is vetted, verified and reformatted ready for archiving and subsequent analysis, with the information from the vetting procedure being passed to the data vetting centre (DVC) of the field measurement group for inspection and possible remedial action. Any failures should be identified as the information passes along the route.

The magnetic cartridges used to carry the information are of considerable importance because the data is recorded only once. As a consequence, they are the subject of particular attention. Starting at the DVC, the magnetic cartridges are tested and certified before despatch to the recording location. Full cartridges are sent to the operational minicomputer and, after copying, are returned to the DVC for storage until needed. This circulation permits cartridges to be withdrawn as the magnetic medium deteriorates.

There is also a data-sampling path between the DVC and the remote recording location—referred to as path 1 in Fig. 1. The recording system in the exchange can be polled over the PSTN and instructed to produce an on-line output, which can be inspected to ensure satisfactory performance of the recording. This facility permits any changes to be monitored before they adversely affect current data.

Connexions to Exchange

Fig. 2 shows that some selectors/relay-sets are permanently wired to the monitoring equipment by direct cabling, and other circuits appear on a flexibility frame. The points to be monitored for the entire period of the experiment are directly cabled, while the use of the flexibility frame allows for growth and changes in recording requirements. Existing cabling and access points are used wherever possible to minimize the amount of work necessary to connect the recording equipment.

The Data Recording Unit

The individual circuit data recorder, which is shown in block diagram form in Fig. 3, is designed to collect, simultaneously, the number of seizures and the traffic carried on each individual device that is connected to it.

The equipment is of solid-state design and modular construction. It can be expanded from 1 input unit to a maximum of 16 input units, each input unit having 1000 monitoring inputs. Any size of system can be programmed to assemble the data from inputs into a maximum of 2000 groups. Each of the separate groups can contain a maximum of 75 devices or circuits. Power is derived from the exchange 50 V supply via a power unit; there is also a 250 V AC connexion, which provides a 50 Hz synchronous supply for the crystal oscillators in the equipment.

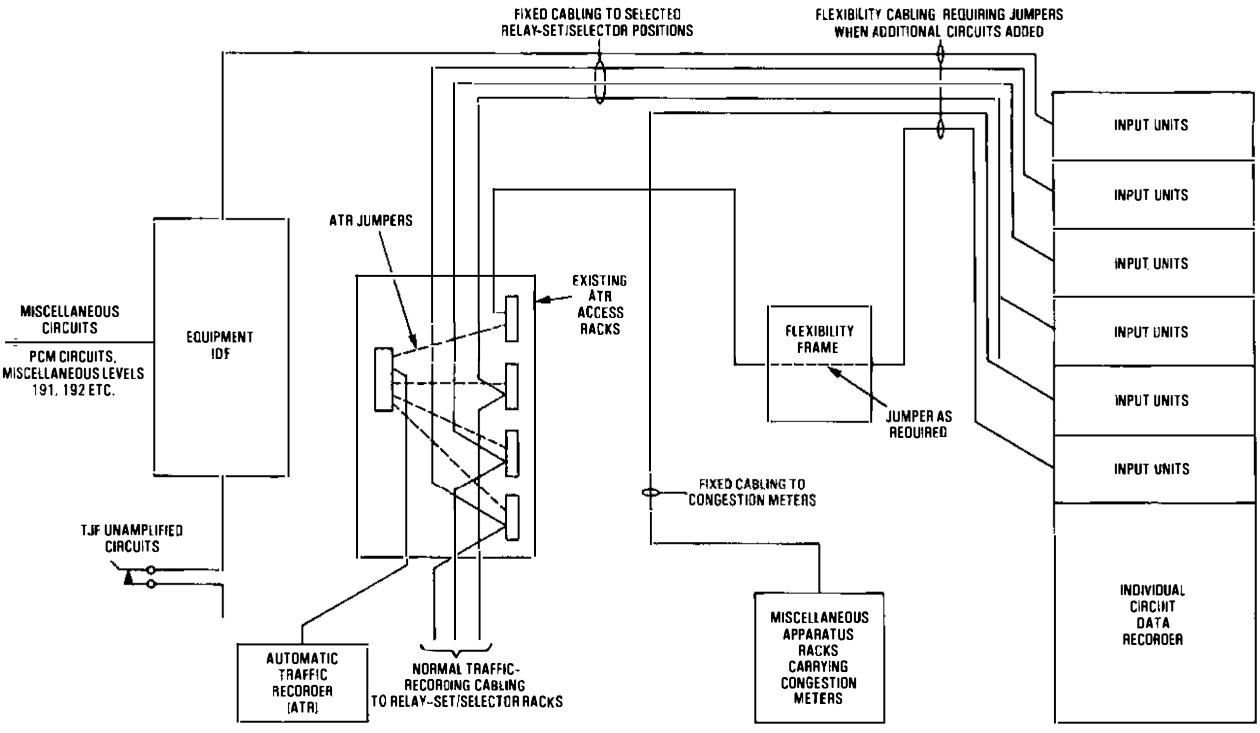
Fig. 3 shows: one input unit with its 1000 inputs; the scan sequence and the adjustable transient response; the dual memory cells for call-count and traffic-carried data; and the control unit.

There are two memories in each of the input circuits:

(*a*) one registers the number of seizures and is analogous to a call-count meter; and

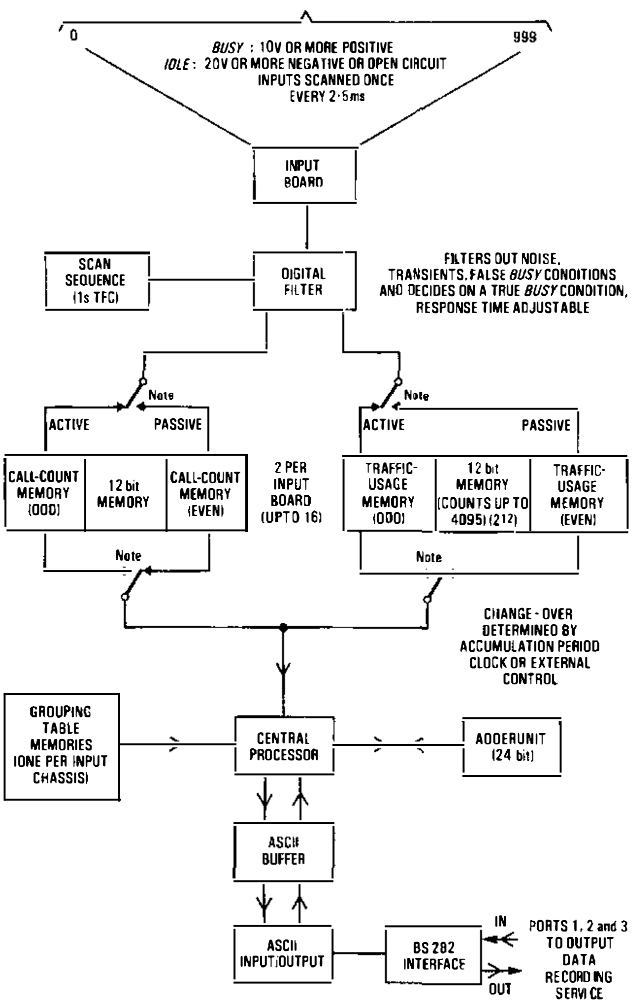
(*b*) the other registers every time the circuit to which it is connected is busy during a traffic recording scan and is equivalent to a traffic meter on each circuit.

The diode gates in the input unit permit each lead to be scanned once every 2·5 ms and perform the same function as access uniselectors.



PCM—Pulse-code modulation TJF—Test jack frame IDF—Intermediate distribution frame

FIG. 2—Block diagram of connexions to the exchange



Note: Change-over determined by accumulation period clock or external control
ASCII—American standard code for information interchange

FIG. 3—Data recording unit

The signal on a lead is passed to the digital filter, any noise and transients are filtered out, and a decision is made as to whether or not the signal is a true one. The response time for this decision-making process is adjustable between 20 and 320 ms. A response time is chosen that ensures contact bounce and P-wire disconnexion during cleardown do not cause multiple events to be recorded. A correct signal of a change in state from *free* to *busy* causes the call-count memory to increment by one count. Every second, a further scan is made; any lead that is still busy is registered as a traffic count and the associated traffic-usage memory is incremented by one unit.

The call-count and traffic-usage memories are duplicated and they work in odd and even pairs; while one call-count and one traffic-usage memory are actively storing data during the scanning period, the other pair are holding data stored during the previous accumulation period. At the end of the accumulation period, the memories reverse roles. The accumulation period is adjustable at 15 min, 30 min or 1 h intervals. At the end of each period, the contents of the passive call-count and traffic-usage memories associated with individual input leads, allocated to a particular circuit group, are added together. The totals for each circuit group are then transmitted to an external storage device; that is, the cartridge recorder.

In the case of the grouped output, the totals are produced by an interaction between the central processor and the grouping table memories. If individual circuit information is required, this interaction is not necessary and each input is outputted in turn.

ANALYSIS

Although this article does not deal with the analysis of the data, certain aspects of the analysis procedures influence the choice of collecting process. If the methods of validating and archiving the collected information are known, the best format for the output data from the traffic-recording process can be chosen. The relative importance of missing or suspect data should be made known to the staff collecting the traffic or call quantities, so that they can take appropriate action when unusual events occur. Knowledge is required of how the data is to be stored before final analysis so that the staff collecting the information can associate the relevant validation and state-of-the-exchange information with the appropriate collected traffic data.

As the analysis continues, it may be necessary to collect extra readings, or whole new sections of additional data, to verify the initial findings and trends of the analysis. The converse is also true; when certain facts have emerged, it may be possible to reduce the amount of data collected and stored.

SUMMARY AND CONCLUSIONS

As a long-term collection exercise proceeds, certain aspects take on a different importance from that originally envisaged; these criteria can be evaluated only when a considerable amount of data has been collected and assessed. One of the most important of these points is how long the results from the analysis are likely to be valid. If there are many and varied changes in the analysed data, it may have little long-term value and could prove useful only in planning another more comprehensive measurement exercise. The cost of running a long-term study could cause the financial and manpower resources commitment to be reviewed and, in some cases, the study may have to be abandoned before its expected end. However, the eventual cost benefits, or penalties incurred from not having the information, may be such that, despite many difficulties and increasing costs from those initially catered for, the collection of the data must continue. These consequences require careful identification and monitoring at all levels.

A major difficulty with any proposed scheme is the number of different people involved and, the longer its expected life, the greater is the likelihood that there will be staff changes during the time span of the work. It may be impossible to regain expertise; for example, if commercial training given to the staff at the commencement of a task cannot be repeated for the replacement staff. Thus, longer-term measurement exercises offer the better prospect of detecting trends, but shorter-term measurements may be easier to manage in the operational sense.

The criteria used in determining the sample choice must continue to be satisfied by the sample under observation for the entire study period and not just during the shorter term. Investigations into customer behaviour require great care, because the status of individual customers can change with time; certain sample points may have to be replaced by new choices to maintain the overall sample population in its original condition.

It has only recently become possible, with the use of modern technologies, to investigate many of the problems in tele-traffic engineering. Perhaps, in the future, such exercises will have a profound effect on dimensioning methods for new plant and the maintenance of grade of service on existing plant. The authors of this article look forward with enthusiasm to reading details of the analysis and conclusions based on the information collected during the exercise described above.

A Telephone News Service Using Microprocessor Control

A. PHOENIX, B.ENG. †

INTRODUCTION

Teleradio, whereby customers dial a radio broadcast, was first introduced in the Liverpool Telephone Area in 1976–77 and has been highly successful. The revenue generated is producing a remarkable return on the very small capital assets employed. In Liverpool there are 2 services: one gives access to the local commercial radio, *Radio City*, by dialling 194, its medium-band wavelength; and the other to the BBC local station, *Radio Merseyside*, by dialling its medium-band wavelength, 202. It had been realized for some time that the hourly news bulletin were very popular. Fig. 1 shows a typical trunk-occupancy curve during a 24-hour period. Only commentary on Liverpool or Everton football matches has competed with the demand for news.

Other information services, particularly the highly popular racing results service, have required increasing numbers of access relay-sets. It became evident that provision of a news service could have a number of advantages: it could avoid the hourly congestion, satisfy a greater number of potential customers wishing to listen to the news, and increase the total number of successful calls. By spreading the demand, the 3 services could be provided by using fewer access relay-sets than were required for the 2 existing services. It was also expected that the proposed service would increase the number of people attempting to call the news: with the hourly service many subscribers miss making the call on the hour and then do not call later. Thus, customers who had not hitherto considered using Teleradio as a news source when away from a radio could be attracted to the service.

THE SYSTEM

Methods of producing a low-cost news service which excluded manual intervention were investigated. The solution decided upon achieves automatic updating of the news almost every hour throughout the day by using 2 Neal-Ferrograph 302 solenoid-operated stereo cassette decks, a modified Answering Set No. 2A and simple microprocessor control. The task that the logic circuitry is required to perform is within the capability of transistor-transistor logic devices. However, when the microprocessor was tried, it became evident that it would also be useful for improving the reliability and flexibility of the service; it allows decisions to be made about methods of maintaining a service if parts of the system fail. The microprocessor chosen was the Science of Cambridge Mark 14 development system, which provided the required facilities at the lowest cost.

† Liverpool Telephone Area

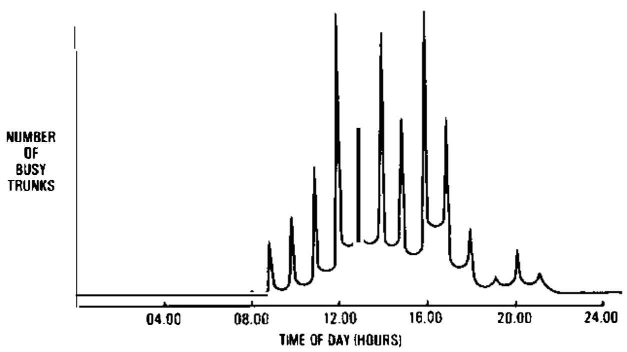


FIG. 1—Trunk occupancy for Teleradio service

The news bulletins providing the source material are those which Radio City transmits. These bulletins vary in length from about 2 min to half-an-hour; it was felt that using a clock to control the start of recording was too much of a risk, since the start of the bulletins vary by up to 10 s and a subscriber might interpret 10 s of silence as a failed call when in fact he had been charged for the call.

The solution to the problem was not as easy as it might seem, particularly with regard to an automatic system. The traditional solution favoured by the British Post Office has been to use a manually updated system, which uses a hand-made loop of tape for each recording, or an Announcer No. 11A, which is a drum device.

The Announcer No. 11A seemed to provide solutions to the problems; but it was eventually ruled out as its maximum recording time was normally only 4 min (although 6·5 min can be achieved). Teleradio's news bulletins were timed to last for 2–9 min; the longer bulletins referred to earlier were discounted as being unsuitable. The cost of the Announcer No. 11A machine, rack and associated control equipment was high; there were also maintenance problems which it was felt could be avoided. Moreover, the Announcer No. 11A is not designed for automatic operation, and controlling logic would still have had to be designed for it.

The main requirement for the service was to provide a continuous message that did not have a break exceeding about 8 s between the end of a bulletin and its re-start. Various investigations that were carried out showed that the average cassette recorder took about 15 s to rewind a 10 min message, which was about twice as long as desired. At one time a machine capable of rewinding a tape in 7 s was located, but unfortunately the company ceased to manufacture it. The other main alternatives were to use 4 machines in 2 pairs, or 2 machines with an announcement from a continuous loop device to cover the rewind period. The first method requires the recording to be made on 2 machines, which then cycle: as one plays the other rewinds. This is a very attractive system; it can operate without breaks and it treats the machines kindly, as their overall duty cycle is only 25% (each pair of machines operates for an hour and then stands-by for an hour). However, since this was a trial system, the second method of operation was chosen to keep costs to a minimum.

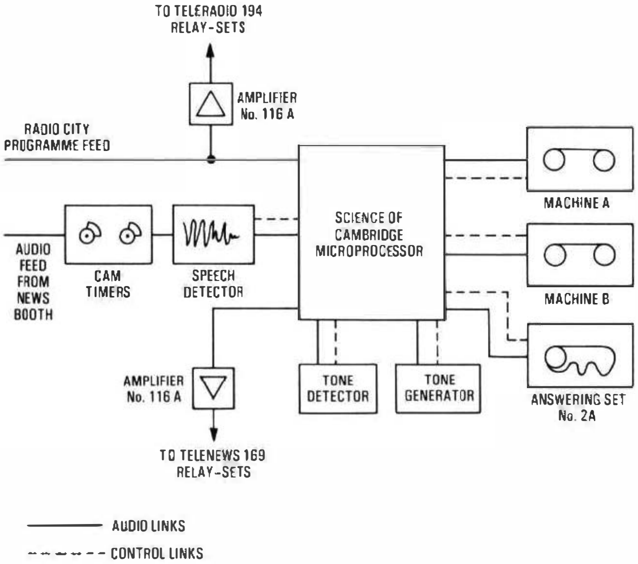


FIG. 2—Block diagram of the system

The problem of recording the news automatically was solved by using a voice-operated switch connected to the news booth; this method is described in more detail later. A block diagram of the system is shown in Fig. 2.

OPERATION

In normal running there will be a news bulletin on one track of, say, machine A. On the other track there is a 4 s burst of 400 Hz tone, which starts at the end of the news. When the end of the recorded news is reached, a tone detector, which is monitoring the control track, signals this fact to the microprocessor. The answering set is then started and its output switched to line. The 15 s that it takes the cassette recorder to rewind are used to provide a recorded description of the Telenews service. After rewinding has been completed, the tape-stop sensor signals to the microprocessor. When the answering set signals that its loop has completed a run-around, the microprocessor starts machine A and switches its output to line; this cycling continues for an hour. The answering set output avoids subscribers hearing silence during rewind.

In the meantime, when a newsreader at Radio City is about to read a bulletin, he brings the news studio into use by pushing up a slider. An audio feed from the news booth is connected to a voice-operated switch in the telephone exchange, and this signals the presence of speech to the microprocessor. The station's programme feed is then switched to machine B, which is started in the RECORD mode. All silences are timed by the voice switch and the first one that exceeds 4 s results in a burst of 400 Hz tone being applied to the control track. When the tone burst finishes, the machine is rewound and stopped; it then waits in the READY mode.

After machine A has completed its next cycle, the answering set switches in the recorded description of Telenews. When its loop has been completed, machine B is switched into service with the fresh news bulletin while machine A rewinds and stands waiting to record the next news bulletin.

Because from time to time the news studio is used for other purposes, a cam-timer closes off the control circuit except for a period from one minute before each hour to 15 min after the hour, so that any use or movement of the slider will not result in material other than news bulletins being recorded. A second cam-timer is used to cut off the 2 half-hour bulletins which occur every day. There is no evidence from the Teleradio occupancy figures that there is a demand for these bulletins from telephone subscribers: the service is seen as a quick reference to main items of news. A subscriber who encounters a half-hour bulletin might not be willing to wait for up to 30 min for the main items of news. As each news bulletin is recorded, it is timed by the microprocessor, and any recording of less than 90 s duration treated as being erroneous. This can occur if a news reader cues-up his cartridge machines or tests the microphone just before or just after the news while the recording equipment is primed. If such a short message is recorded, the machine rewinds but is not switched into service; it waits until a full-length recording is available. A short message can also be created if there is an excessive silence in a real bulletin. Fortunately, the style of presentation on commercial radio ensures that these occurences are rare. If such occurences take place, one of 2 actions results. If less than 90 s of the bulletin has been broadcast, the whole bulletin is rejected and the previous bulletin played for an hour longer than usual. If over 90 s has been broadcast, an incomplete bulletin is used; however, in these circumstances the most interesting material is usually in the section recorded.

If a machine fails to start on cue, the microprocessor checks for a valid news bulletin on the other machine and, if the machine is free (for example, it is not in the middle of a recording), the microprocessor switches it back into service, brings in an alarm, and plays the old bulletin for a further hour. If the machine is not free or does not have a valid news bulletin, repeat attempts are made to start the jammed machine and an alarm is again given. Although the cassettes chosen have been selected for the robust mechanical properties of the tape, their sound quality is far superior to that of the Announcer No. 11A, the nearest functional equivalent generally available for this type of application.

The service provided is not edited quite as smoothly as that which can be achieved by manual editing. Nevertheless, it provides a reliable and increasingly popular service.

MOUNTING

The complete system, which is housed in a wall-mounted cupboard, can be seen in Fig. 3. The 2 recording machines and the Answering Set No. 2A can be seen on the upper shelves, together with an amplifier for monitoring the service. At the bottom there is a spare cassette machine and a spare answering set, which have been connected together to form an independent stand-by system. A spare microprocessor and interface card have also been provided; these can be seen on the left side. So far none of this stand-by equipment has had to be used, and the system, which has now been in public service since January 1980, has proved to be remarkably free from faults.

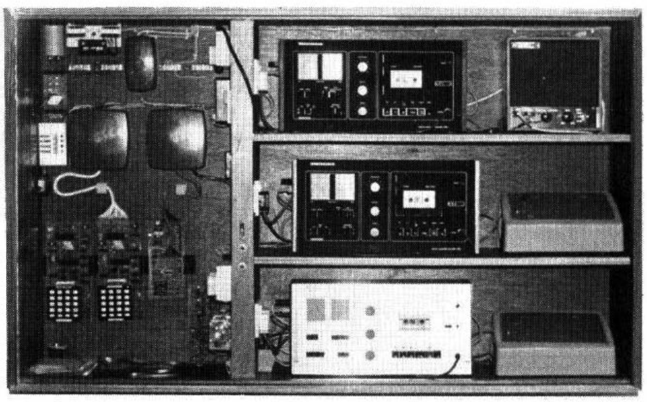


FIG. 3—News service equipment

World Administrative Radio Conference, Geneva 1979

D. J. WITHERS, C.ENG., M.I.E.E.†

UDC 654. 07: 061. 3

The World Administrative Radio Conference, held at Geneva from 24 September–6 December 1979, was convened to revise the main provisions and articles of the international radio regulations applicable to all radio services and the international frequency allocation table. In general, the conference did not consider regulations dealing solely with any one individual service; such detailed revision was deferred to specialist conferences to be held in accordance with a programme laid down by the Conference.

INTRODUCTION

Some 2000 delegates, representing 142 member states, attended the World Administrative Radio Conference, Geneva 1979 (WARC '79): the high level of attendance and representation was unprecedented in the history of conferences held under the auspices of the International Telecommunication Union (ITU). The UK delegation, which numbered 48, included 9 delegates from the British Post Office (BPO).

The WARC '79 was convened to revise parts of the radio regulations applicable to all radio services and, in particular, the whole of the international frequency allocation table.

For the UK and the BPO interests the outcome of the WARC '79 was generally satisfactory, but the increase in the number and complexity of minority and national allocations in footnotes to the frequency allocation table will make future revisions of the table very difficult. Several issues were deferred for consideration by the series of specialist WARCs which are scheduled to meet over the next decade.

The new radio regulations drawn up by the WARC '79 will come into effect on 1 January 1982.

From the viewpoint of the BPO, the more important results of the conference are summarized below.

THE FIXED AND MARITIME SERVICES BELOW 30 MHz

The BPO sought the use of more bandwidth below 30 MHz for maritime services, and would have accepted cuts in the corresponding fixed-service frequency allocations which the BPO no longer uses extensively. The BPO proposals were supported by other UK delegates but with more emphasis on the expansion of HF broadcasting allocations; there was support from abroad for this viewpoint. However, the opposition from other countries to any reduction in the fixed-service frequency allocations below 10 MHz was too strong to allow additional exclusive allocations to be made to the maritime service. Nevertheless, expansion was achieved at 4 and 8 MHz on a shared (primary) basis and it will be possible to utilize this expansion in a satisfactory manner.

At frequencies above 10 MHz, increases in the exclusive maritime bands were achieved in line with the UK proposals.

LAND-MOBILE AND MARITIME-MOBILE SERVICES AT VHF AND UHF

The BPO had sought a large increase in the VHF/UHF bandwidth allocated for mobile services and, in particular, for land-mobile services. The WARC '79 decided to make new frequency-allocations for the mobile services in the bands 41–68 MHz, 174–223 MHz and 862–960 MHz. In each case, these new allocations are to be shared with other services, chiefly broadcasting services. However, there was a large measure of agreement amongst Western European countries on the need to make use of these bands for the land-mobile service. Use of these bands will be introduced stage-by-stage following the necessary planning conferences. The World Administrative Mobile Radio Conference, which may be held in 1982, may consider whether part of the new bands can be allocated for the maritime service.

TROPOSPHERIC-SCATTER SERVICES TO OFF-SHORE PLATFORMS

The fixed-service frequency allocations in the 2–2·6 GHz frequency range were not changed to any significant degree. Additional sharing with various space services was agreed; this may complicate the planning of new tropospheric-scatter links, but the effect should not be severe. Thus, the WARC '79 decisions should not hamper any future expansion to these services as foreseen by the BPO.

MARITIME-SATELLITE SERVICES

The International Maritime Satellite Organization (INMARSAT) had proposed that, at around 1600 MHz, a bandwidth of 15 MHz should be provided for each direction of transmission between ships and satellites instead of the present 7·5 MHz; the BPO agreed with this proposal. It was also proposed that an additional 5 MHz be allocated for ship-to-satellite transmission to cater for real-time transmission of seismic data. These proposals were agreed by the WARC '79 except that an increase to 14 MHz only was approved, but some parts of the new band will not become available until 1990.

THE FIXED-SATELLITE SERVICE FOR INTERNATIONAL CONNEXIONS

The BPO's proposals for the fixed-satellite service for international connexions were to increase the bandwidth allocated for international services from 500 to 1000 MHz in the band 10–15 GHz, and to exclude totally the feeder links for broadcasting satellites from the up-link band. The increase in bandwidth was approved, but the proposal to exclude the broadcasting satellite feeder links was rejected. However, these feeder links should not prove to be a serious hindrance to the international networks because spectrum was allocated elsewhere specifically for this purpose.

There was a strong argument put forward at the conference for an increase in the bandwidth allocated to the fixed-satellite service operating near the 6 and 4 GHz bands, despite the use already made of this part of the spectrum for other services; in particular, the radio-location service. It was agreed that

(*a*) an extra 100 MHz of bandwidth would be made available to all countries from 1982,

(*b*) a further 300 MHz of bandwidth will be available for use by most countries except the UK and some European countries, and

(*c*) ultimately, a further 200 MHz of bandwidth will be

† International Executive, Telecommunications Headquarters

transferred from radar applications to the fixed-satellite services; it is not yet known when this transfer will be made.

The above decisions were beneficial to the International Telecommunications Satellite Organization (INTELSAT) and to the BPO.

At higher millimetric-wave frequencies (30–275 GHz) the conference decisions for the fixed-satellite service were at least as good as the BPO had sought, but these additional bands are not likely to be used commercially for many years.

Some countries were concerned that they would not find room in the geostationary orbit for domestic systems scheduled for service in 10 or 20 years time. The WARC '79 agreed that a conference should be convened sometime in the period 1984–86 to discuss how access to the orbit and spectrum could be assured, by planning or by other means.

RADIO-RELAY AND MILLIMETRIC-WAVE DISTRIBUTION SYSTEMS

At frequencies below 1 GHz, the availability of bandwidth for radio-relay systems will be restricted because of the demand for the use of more spectrum for land-mobile services.

Between 1 and 40 GHz, the fixed-service frequency allocations have not been affected to any great extent. This decision was expected and is not a cause for concern since there is already unused bandwidth in the upper half of this block of frequencies that could be made available for the BPO radio-relay services.

No previous WARC had authority to allocate frequencies above 40 GHz for terrestrial services. However, the WARC '79 made considerable frequency allocations for the fixed service, both in the atmospheric absorption bands and in the 'windows'; these bandwidths should be suitable for both short-range radio-relay systems and local distribution systems when the need arises.

CONCLUSION

The revised radio regulations and international frequency-allocation tables determined by the WARC '79 will govern the provision and use of all radio services for many years.

Book Reviews

Microprocessors: Principles and Applications. M. J. Debenham. Pergamon Press. vii + 90 pp. 14 ills. Hard cover: £7·50; paperback: £3·75.

This little book undertakes a subject which has been tackled by many authors—introducing microprocessors to beginners.

Regrettably, like many others, this one fails in its objective. The subject matter pertaining to microprocessors is so large, and background knowledge requirements so diverse, that a book for beginners needs to be written very carefully. If this care is not taken, the book will omit important points and over-emphasize other points. This is what has happened here. The author has treated the subject from the point of view of an expert in main-frame computers, and this has led to a confusing approach to the operation of a microprocessor and to somewhat haphazard and occasionally inaccurate terminology.

The introductory chapter is fairly conventional, but it talks of manufacturing processes, such as p-channel silicon-gate, without explaining them. It would have been better not to have mentioned process names at all at this early stage. The book also appears to have been written over a period of time, since this chapter states that the single-chip microcomputer is not yet available, whereas by the end of the book it is available.

The chapters covering microprocessor operation and programming are poorly constructed. Topics are introduced without warning; for example, the hexadecimal code, D4B, suddenly appears with no previous explanation of it. Too much emphasis has been placed on microprogramming. Apart from the fact that many microprocessors are not microprogrammed, it is not important for the beginner to possess more than a very simple understanding of this subject. *Interrupt* is introduced before *stack*. The most significant bit of a byte is introduced, without explanation, as a sign bit.

The description of subroutines is confusing: addressing modes that have not been described have been used, and the whole section has been written with a microcomputer-type stack in mind, which is not relevant here.

The three chapters dealing with support systems and design and selection are better than the other chapters, although the author's statement that there is only one source of the 8080 says much about the time-scale of this book.

There are a number of errors in the book. A *nibble* is defined as two bits; firmware is indicated as applying only to microprogramming; what is called a light-emitting-diode display means a 7 segment array; it is implied that memory-mapped input/output is used only on simple microprocessors; PROM is not defined, and RePROM is shown as REPROM in the index.

D. L. GAUNT

Introduction to Microprocessors: Software, Hardware, Programming. A. Leventhal. Prentice-Hall Inc. xv + 624 pp. 301 ills £16·75. Student Edition £9·50.

The author states in his preface that "developing systems based on microprocessors requires understanding of both hardware and software. I have taken the approach in this book that the use of microprocessors does involve a shift in the design burden from hardware to software and I have, therefore, emphasized software." He considers the book to be a general introduction to microprocessors for advanced undergraduate students, who are assumed to have had introductory courses in programming and digital circuits.

The book's contents are organized into nine chapters and seven appendices. The chapters cover, successively, an introduction to microprocessors, microprocessor architecture, microprocessor instruction sets, microprocessor assemblers, assembly-language programming, software development for microprocessors, microcomputer memory sections, microprocessor input/output, and microprocessor interrupt systems. The appendices give convenient information on binary numbers, logical functions, numerical and character codes, semiconductor technologies and memories, instruction sets for the Intel 8080 and Motorola 6800, and a glossary of terms.

The author chose to focus on the widely-used Intel 8080 and the Motorola 6800 for his examples throughout the book, contending that they are sufficiently different from each other to be representative of a range of devices.

The text is considered to meet the author's objective, and the presentation and layout are good. Some might consider the title a little misleading; the book is good on programming and an excellent guide to writing assembler programs, but would not be too much use when building the hardware on which to run those programs.

A. G. LEIGHTON

Restoration of a Flooded TXE2 Telephone Exchange

A. G. HODSOLL and R. DAVIES†

FLOODING

On Thursday, 27 December 1979, following a period of very heavy rain, the river Ebbw overflowed its banks at Risca, Gwent. The first report of possible flooding of the telephone exchange, a 3000-line TXE2, was at 11.45 hours, when the site flooded to a level above the floor of the exchange. The quantity of water entering the building was restricted by barricading the doors with pieces of wood and rubber mats; the water which did enter the exchange was allowed to flow into the cable chamber, where jointers' pumps were used to pump out the water. Fire brigade assistance was sought, but a powerful pump brought into the exchange failed to start. The AC mains supply was disconnected when the water level reached the socket outlets at the foot of the racks. At 15.00 hours, water burst through the wall ventilators, quickly filled the cable chamber and started to flood the exchange. Work was initiated to remove the lower slide-in units and these were stored, together with the exchange records, in the attic. At 15.15 hours, with water outside the building more than 1 m deep and rising, and on the strong recommendation of the fire brigade, staff were evacuated from the building. Fig. 1 shows the flood level in the vicinity of the exchange. Water in the exchange finally rose to a level 800 mm above the floor and service was lost completely.

When it became evident that the exchange was at risk, the emergency authorities were notified. The police stationed a radio car on high ground above the town to provide fire look-out. Preparations were made for restoring emergency telephone service for the town, but little could be done until the weather conditions improved and the flooding abated.

RESTORATION

By the morning of Friday, 28 December, the flood water had receded and access to the exchange was possible at 06.00 hours. Lighting was quickly restored and cleaning operations commenced. Large trolley-type and hand-held hot-air blowers were used to dry the equipment whilst the dried mud was loosened by using brushes, and removed with vacuum cleaners. Figs. 2 and 3 show the level reached by the flood water and the state of the exchange at midday.

The British Post Office (BPO) factory at Cwmcarn, 5 km away, offered washing, ultrasonic-cleaning and drying facilities for slide-in units and rack-mounted relay-sets. Following the cleaning, a working party of Cardiff area staff worked on renovation and relay adjustment at Cwmcarn throughout the evening and night. Rack and frame cleaning continued with 24-hour staffing. The power-plant rectifiers were cleaned and dried on site and damaged cells in the exchange battery were replaced. A 3-phase mobile generator was connected in place of the damaged engine set and engine-control cabinet.

Priority was given to drying the main distribution frame (MDF), so that junction cables and emergency lines could be tested, followed by an assessment of faulty local cables and cabinets.

At 07.30 hours, a specially equipped emergency caravan was despatched from Cardiff and positioned in the town centre, close to the exchange. The caravan gave an emergency

† Cardiff Telephone Area

FIG. 1—The level of flooding in the vicinity of the exchange

(Picture by courtesy of the South Wales Argus)

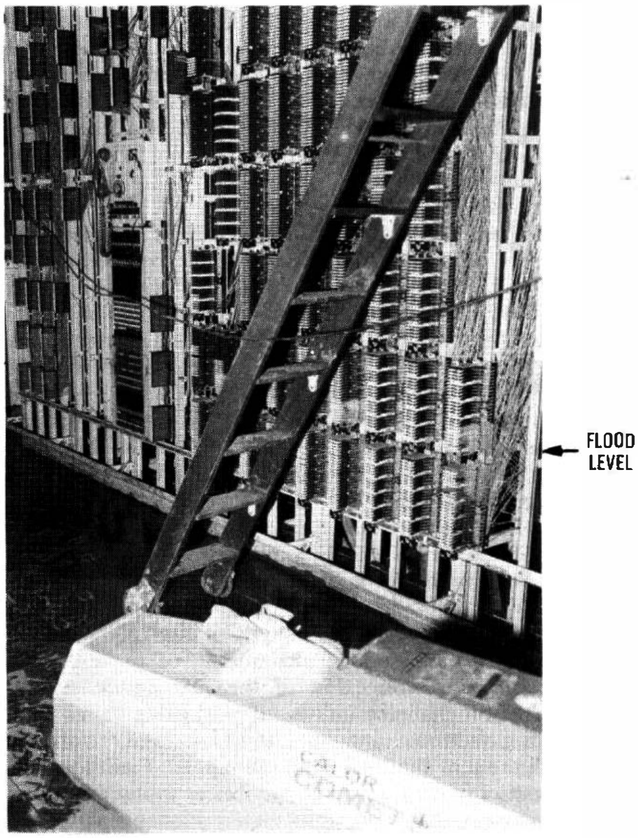


FIG. 2—The main distribution frame after the flood had receded

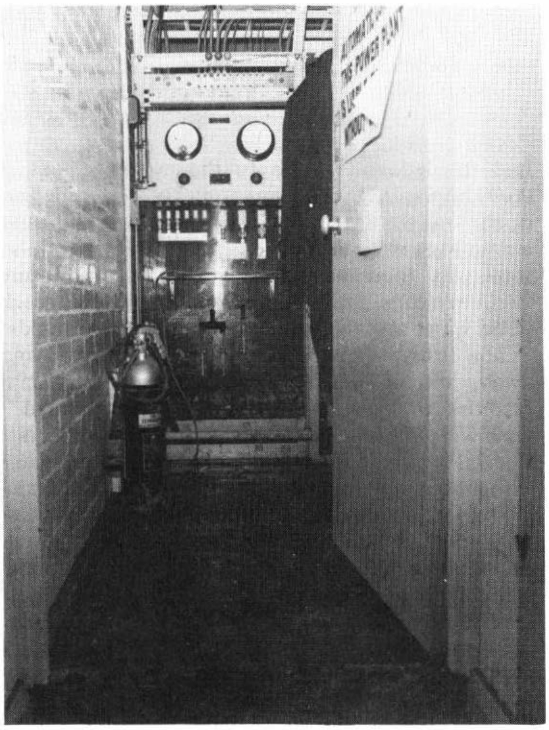


FIG. 3—The power-control rack after the flood had receded

service to the public by means of radio telephones. By midday, all junction cables had been tested and it was found that only one cable to Newport group switching centre (8 km away) was in working order. This cable was used to provide out-of-area exchange lines for the police, and 14 telephones for public use located in the emergency caravan and in some nearby shop premises which were taken-over to serve as a telephone advice bureau staffed by telephonists and travelling supervisors. Six kiosks, away from the flooded area, were given service on Newport exchange by bunching junction cable pairs.

On Saturday, 29 December, a 300-line mobile exchange (MNDX) was delivered to Risca to give service to emergency and business customers, and work commenced to connect customer and junction facilities. Cleaned TXE2 equipment was returned from Cwmcarn factory and fault location on the registers and control rack commenced by using a temporary DC power supply. By the end of the day, one security side of the control rack was working, 10 of the 18 registers could set up and return dial tone, but only one register had all facilities in working order.

During Sunday, 30 December, the DC power plant was fully restored and also an edge-connector problem was identified: the pins on which the wire-wrap connexions were made on Connectors No. 206 (female edge connectors fitted on racks) were found to be badly corroded. Further investigation showed that mainly pins carrying battery or earth connexions had been severely damaged by electrolytic action. This was due to the sudden abandoning of the exchange which prevented disconnexion of the DC power supply. Work started on changing individual pins, using stores from neighbouring electronic exchanges. It was necessary to change 10% of all the pins that had been submerged. Fault location on the registers indicated a large number of faulty reed-relay coils, many more than were immediately available as spares. New registers were borrowed from Rhiwderin exchange, where a new TXE2 exchange was being installed.

By the Sunday evening, spare slide-in units from other TXE2 exchanges enabled the full control rack to be restored. This, plus the new registers, highlighted that almost all supervisory units and subscribers' line units which had been submerged were faulty and would take too long to repair. It was therefore decided that the quickest way to restore service would be to replace the plug-in units.

On Monday, 31 December, a list of all slide-in-unit requirements was passed to Wales and the Marches Telecommunications Board Headquarters for possible replacement by Supplies Division. It soon became clear that only a very small quantity of the required units could be replaced from this source and it was decided to borrow the replacement units from Rhiwderin. Because of incompatibility problems, it was necessary to modify some of the units and to borrow some units from 10 other exchanges in the Cardiff area.

Matrix testing, using the Telecommunications Headquarter's prototype matrix tester, and path analysis, using a selected-path analyser, had continued throughout Sunday and Monday nights and, by 14.00 hours on New Years' Day, sufficient confidence in the exchange allowed the progressive re-introduction of those customers whose lines were not faulty. (Testing and external fault clearance had been in progress since 28 December.) As the TXE2 local-call timing equipment had been badly damaged, local-call timing was provided by connecting the TXE2 metering circuits to the metering equipment in the MNDX. On-site repairs to the stand-by engine set and engine control cubicle were also completed.

Temporary service was given to 300 business and emergency customers via the MNDX on 1 January. These customers were not reconnected to the TXE2 exchange until 14 January, when experience had proved the reliability of the exchange.

By 5 January, two shelves of 50-point linefinder equipment on an expedient rack had been replaced; and the bottom shelf of the coin-and-fee checking equipment rack was refurbished and the relay-sets replaced by new ones.

A 5-caravan mobile electronic exchange, capable of replacing the complete TXE2 exchange, was positioned in a school playground adjacent to the exchange site. This had been planned as a precaution against failure to restore the exchange, but in fact was not used.

MAINTENANCE SINCE RESTORATION

Since restoration of the exchange, dust on Type-12 relay contacts in subscribers' line circuits has been the predominant cause of fault reports. This dust was due to the forced drying operation by hot-air blowers. Because of visible corrosion, the pins of connectors serving tone circuits on subscribers' line racks have been replaced with no loss of customer service. Vacuum cleaning has been a continuous operation and will continue for some time, because dust continually reappears. Work remains to replace those parts of the MDF and test-jack frame which were submerged.

To date, the fault rate has been higher than before the flood, but shows a downward trend. There have been no further failures of edge-connectors.

METALLURGIST'S REPORT

An inspection of exchange equipment above and below the flood level was made by BPO Materials Section, which concluded that a higher than normal fault rate can be expected to persist due to:

(*a*) Abrasive dust, causing contact problems and edge-pad failure due to the removal of the gold plating. This applied to all equipment in the exchange.

(*b*) Failure of exchange wiring due to corrosion of wire wraps that had been below flood level.

It was also concluded that, if flood-damaged slide-in units were repaired, they would certainly have a higher than normal failure rate due to corrosion.

CONCLUSIONS

In circumstances of flooding, and when equipment is likely to be submerged in water, all AC and DC power supplies should be disconnected. It is accepted that the final decision must be made by the man on the spot.

H-type buildings suffer particularly in a flood situation because the MDF is only accessible through the apparatus room, which aggravated the dust and dirt problems at Risca.

Restoration would have been facilitated if a national stock of compatible slide-in units, for use in such emergencies, had been available.

STAFF EFFORT

Dealing with a disaster of this magnitude called upon the resources of every division of the Telephone Area. It is with pride in the ability and loyalty of the staff that one can report on the excellent way in which they responded to this challenge; many staff were recalled from Christmas and New Year leave to work in unpleasant conditions for long hours, The support of the Managing Director, Telecommunications, Mr. P. Benton and the Chairman of the Wales and the Marches Telecommunications Board, Mr. K. Spurlock, was appreciated when they visited the site during restoration.

Post Office Press Notice

UK TO GET WORLD'S LARGEST RADIOPAGING SYSTEM

A new radiopaging service, designed and made in Britain, starts later this year and, when complete in 1982, will cover most of the UK—to become the largest of its kind in the world.

At present the British Post Office (BPO) runs a radiopaging service in London covering 2400 km², which started with a trial service in the Thames Valley area. Some 30 000 pagers are working on these systems and the BPO has just placed orders for an extra 70 000 to be supplied by Multitone, Motorola and Standard Telephones and Cables at a cost of £6M.

Explaining the BPO's plans for its new nationwide network, Mr. Peter Benton, managing director of the telecommunications business, said that the success of the London and Thames Valley services had led to a demand for paging from other parts of the country. The BPO is meeting this demand in the first instance by special extensions of the London system to selected cities. Already, service is available in Aberdeen, Birmingham, Bristol, Cardiff, Glasgow, Liverpool and Manchester.

Mr. Benton said: "We are now bringing in a major new national service which will be able to accommodate up to about a million and a half users. When complete, it will be the world's largest single integrated paging network".

To operate the new service, the country will be divided into 40 national paging zones. Very-high frequency (VHF) radio transmitters in each zone will be controlled by a network of new computers called *paging control equipments* (PCEs).

One of the attractions of the new network is that the customer can tailor the service to suit his individual needs. He does this by selecting the zones in which he wishes to be paged. Paging can be restricted to one particular zone, or extended zone-by-zone to cover the country. Pagers on the national system will be available with two paging numbers, enabling users to be called from two separate places, such as home and office. Pagers with this facility—known as *second address*—emit two clearly distinguishable bleep signals. Group calling, which allows up to 99 pagers to be alerted by a single call, will also be available.

When the first of the new PCE controllers starts operating later this year, its first job will be to take over the existing service in the capital, plus its extensions to the seven other cities. Customers will hardly notice the change, because their pagers will continue to operate without modification. Next year, however, when the Thames Valley trial service is absorbed into the new network, arrangements will be made for customers there to get new pagers.

At the centre of the service are the PCEs. At the core of each is the paging control processor—two GEC 4070 minicomputers, one working, the other a stand-by. Each computer consists of a central processor, 256 kbyte of core store, a high-speed random-access drum store of 4 Mbyte capacity, 4·8 Mbyte cartridge discs and interfaces with the telephone network and encoding equipment.

This installation can accommodate up to at least 100 000 paging numbers and, in the first phase of the network, five PCE installations are envisaged. The number of PCE installations will then be progressively increased as needed to cater for growth to maximum capacity.

In essence, each PCE accepts the relevant digits of the dialled paging number, identifies the pager being called and then switches on the radio transmitters in the appropriate zone or zones to broadcast signals that set the pager bleeping. Each paging number consists of ten digits. The first (0) tells the local exchange that the caller has dialled a national number; the next three (073) indicate a paging call to route it to the nearest PCE installation. The remaining digits identify the individual pager. The control processor receives only these final six digits, and uses them to generate a seven-digit paging number which identifies the home PCE (the centre to which the number is allocated) as well as the pager itself. The call is then sent on to the home PCE (if different from the PCE receiving the call) which takes control. The home PCE confirms that the paging call is valid and acts on it in two ways. It activates a recorded announcement which tells the caller "paging call accepted" and it converts the seven digit paging number into a binary paging code, which it transmits to the appropriate paging zone or zones. If the user wishes to change his elected zones, this is done simply by altering the record in the home PCE.

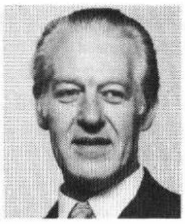
Each zone has its own zone transmission controller (ZTC). The paging signals from the PCE encoder pass to the ZTC where they fan out to all the transmitters in the zone. The transmitters broadcast the paging signals in unison in a frequency-shift keyed mode.

Eventually, more than 250 VHF radio transmitting sites will be used to provide national coverage. The transmitters are Redifon PT2100 dual-frequency equipments, with a maximum output of 10 W in the 153 MHz band. They are similar to the single frequency version used for the existing London service.

To give system security, ZTCs, transmitters and interconnecting lines are duplicated. Automatic change-over is provided at each node to guard against failure.

Profiles of Senior Staff

DIRECTOR: BUSINESS PLANNING AND STRATEGY



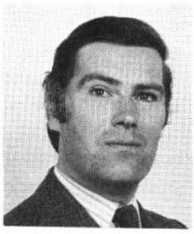
D. WRAY, B.SC., C.ENG., F.I.E.E.

Donald Wray joined the British Post Office (BPO) Research Station at Dollis Hill as a Youth-in-Training in 1942 and became an Executive Engineer in 1947, working on various aspects of television transmission and microwave radio. He was transferred to LMD Branch as a Senior Executive Engineer in 1957 where he was responsible for the maintenance and operation of television links. After one year with Imperial Chemical Industries, as part of an exchange scheme in industry, he returned to the Treasury Technical Support Unit. As an Assistant Staff Engineer in 1962 he became the project engineer for the first satellite earth station at Goonhilly at the time of the *Telstar*, *Relay* and *Early Bird* experiments.

After a year with the Imperial Defence College, he was appointed Staff Engineer of the Main Lines Development Branch and then Deputy Director of Network Planning Department. After several years planning the trunk transmission network, he transferred to the External Telecommunications Executive (ETE) where he was responsible for planning the international network and where he took part in many satellite and submarine cable projects, including the establishment of the Madley earth station. He became Director of ETE in 1975, and of the Telecommunications Development Department in 1976, where he remained until the department was dissolved during the reorganization of Telecommunications Headquarters.

Donald Wray has been Vice-Chairman of the Council of the Institution of Post Office Electrical Engineers, the Chairman of its General Purposes and Finance Committee since 1967, and has recently been appointed as Chairman of the Council and of the Board of Editors of the *Journal* in succession to Mr. J. F. P. Thomas.

DIRECTOR: PROCUREMENT PLANNING



I. D. T. VALLANCE

Iain Vallance joined the British Post Office (BPO) as an Assistant Postal Controller in 1966, having taken a degree in English at Oxford. After a spell in the North West Region and the Planning Division in Postal Headquarters, he was awarded a BPO scholarship to take his Master's degree at the London Graduate School of Business Studies.

Returning from the Business School in 1972, he moved into the Postal Finance Department and worked on the agency-services agreement, the arrangements between the BPO and HM Treasury for the provision of agency services for Government Departments. In 1973 he became Personal Assistant to the Chairman of the BPO, Sir William Ryland.

Two years later, he returned to Postal Finance as head of the Planning Division and in 1976 he was appointed Director of Central Finance Accounting, where one of his tasks was to devise a means of eliminating the massive deficiency in the pension fund, which the BPO had inherited on its incorporation in 1969.

In 1978 he moved into Telecommunications for the first time, as Director of Telecommunications Finance Planning. He took over his present post in November of last year.

DIRECTOR: DATA PROCESSING

J. L. HOWELLS, F.B.C.S.

John Howells joined the British Post Office (BPO) in 1939 as a Youth-in-Training in City Telephone Area. He served in the Royal Corps of Signals during the war, mostly in West Africa where he commanded the Sierra Leone Signal Squadron. He returned to London's City Area to exchange maintenance and transferred to the Traffic Division in City Area in 1950 as Service Superintendent at Bishopsgate and, later, Monarch. After a spell at Regional Headquarters on establishment work, he was transferred to the Central Organization and Methods Branch—his first introduction to computers—in 1957. He was the first senior programmer in the BPO and was responsible for the programming of the first BPO computerized payroll in 1959.

In the early 1960s he was part of a small team which devised a method of computer evaluation based on a *Post Office Work Unit*, which became a standard comparator for over a decade. He was an early member of the British Computer Society and served on its Membership Board for many years. He was elected a Fellow of the Society in 1968. He has seen computing in the Telecommunications business grow from a single-project/single-installation base to a network of 13 computer centres handling hundreds of projects and employing 3500 people—probably the largest data-processing operation in Europe.

DIRECTOR: SPECIAL STUDIES

C. CRUMP, B.A., A.C.C.A.

Camilla Crump joined the British Post Office (BPO) as an Assistant Principal in 1954 after she had attained a first-class degree in mathematics at Cambridge University. She worked for 3 years in the Overseas Mails Branch of Postal Services Department and then for 18 months as Assistant Private Secretary to the Postmaster General. During 1960–1963 she worked as a Principal in the External Telecommunications Executive on the Commonwealth financial arrangements for telecommunications. In 1964 she spent a year in the Broadcasting Branch of the BPO on work that remained with the Civil Service when the BPO became a public corporation in 1969.

She was a founder member of the new Giro Department in 1975, where she spent 4 years covering the policy and legal aspects of setting up the Giro service, before she returned to the Postal Business. On promotion to Assistant Secretary she spent a year in Business Planning and a further two years in Postal Finance. In 1973 she was seconded to PA Management Consultants, and worked for a year with them on the introduction of management accounting systems in a number of different companies.

On her return, she became Head of the Finance Division of the Data Processing Service. Two years later she entered the Telecommunications business as head of the division responsible for investment-appraisal and financial-policy matters in the Telecommunications Finance Department. One of her major tasks in this Division was to set up a capital-project authorization-and-control system. In 1978 she became Director, Central Finance and Accounts, which covered financial and management accounting matters for the BPO as a whole. In 1979 she returned to the Telecommunications Business as Director of Special Studies in charge of the reorganization of Telecommunications Headquarters.

DIRECTOR: TELEGRAM SERVICES

A. M. F. FINUCANE

Tony Finucane joined the British Post Office in 1938 at Richmond, Yorkshire, as a probationary Sorting Clerk and Telegraphist. After war service in Europe and the Far East as an infantry officer in the Green Howards, he became a Sales Representative in York Telephone Area. Joining the Inland Telecommunications Department in 1954, he began an association with sales training which, after spells in Norwich and London's West Telephone Areas, culminated in his heading the National Sales Training School from 1960–1965. He was the first Deputy General Manager (DGM) of North Central Telephone Area in 1966 and was seconded to Telecommunications Headquarters in 1968 to establish the THQ Internal Communication Unit where, among other things, he initiated *Management News*. In 1969 he became GM of London North West Area before being promoted to GM Centre Area in 1977 and to Director Telegrams in 1978.

With six telephone areas and three spells in THQ behind him, Tony finds his latest assignment interesting, stimulating and not a little bizarre, as he and his small team begin to drag the oldest telecommunications service into the world of communicating word processors and the electronic office.

DIRECTOR: PERSONNEL

P. A. LONG, M.I.P.M., F.B.I.M.

Peter Long joined the British Post Office (BPO) in 1937 as a Youth-in-Training in the Lincoln Telephone Area; he remained there until he was conscripted into the Royal Air Force in 1942, where he spent the next 4 years carrying out special studies into electronics development, mainly in the GEC laboratories at North Wembley.

Returning to the BPO in 1946, he became a Technical Officer, but two years later left the engineering field to join the newly reformed sales force as a Sales Representative. Three years later he moved to the old Internal Telecommunications Department (ITD) in London and, in due course, became the Inspector of Sales Establishments.

In 1964, as a Principal Telecommunications Superintendent, he was a founder member of the ITD Organization and Efficiency Branch. In 1968 he moved on to Management Services Department, where his job was to increase the efficiency of the telecommunications business by improving its organization and by establishing the correct levels of authority in it.

Peter Long's last change of direction came in 1971, when he became an Assistant Secretary in Telecommunications Personnel Department. In this job he assumed responsibility for the personnel policy of those grades in which he had served, and for many others. His promotion to Director: Telecommunications Personnel came in 1976. During his term of office, which has coincided with an upsurge in legislation in the personnel field, he became associated with the Institute of Personnel Management, for which he has chaired a number of sessions at its annual conference.

Covering as it does a number of hierarchies and different fields of work, Peter Long's background gives him a fund of commonsense experience on which to draw in his present post. He is now deeply immersed in the major issues of restructuring and the separation of the Businesses, issues which make heavy demands on the personnel function.

For relaxation he turns to amateur radio and hopes shortly to obtain his "ham's" licence.

DIRECTOR: TRANSMISSION

W. G. SIMPSON, B.SC., C.ENG., M.I.E.E.

Geoff Simpson joined the British Post Office (BPO) at Northampton as a Youth-in-Training in 1941 and was soon engaged on transmission work as an Unestablished Skilled Workman and as a Technician. He joined Lines Branch of the Engineer-in-Chief's Office as an Assistant Engineer in 1949, where he worked on the development of carrier and coaxial line systems, including the first regulated line systems. In 1959 he joined the Research Station at Dollis Hill as a Senior Executive Engineer working on 3 kHz channelling equipment for submarine cables, carrier systems for deloaded audio cables and various compandor applications, which included the early work on Lincompex.

He returned to Lines Branch in 1962 to lead a team developing transistor equipment for television applications. He was promoted to Assistant Staff Engineer in 1965 covering most aspects of transmission development, including the first digital systems. At the same time, he became a BPO delegate to CEPT, CCITT and CCIR study groups on transmission matters, chairing working groups on programme circuits and digital-network planning. He is now Vice-Chairman of CMTT, the joint CCITT/CCIR study group on long-distance television and sound-programme transmission. Promotion to Staff Engineer in 1970 took him into Network Planning Department with responsibility for planning the inland trunk network. Further promotion to Deputy Director in 1975 widened his responsibility to include Datel, Telex and submarine-cable activities.

He brings a wide experience of many facets of transmission to this appointment as Director of the newly created Transmission Department.

DIRECTOR: SYSTEM X DEVELOPMENT

J. MARTIN, B.SC., C.ENG., F.I.E.E.

John Martin was appointed Director of the Integrated Systems Development Department in February 1978. The Department, which was retitled System X Development Department when Telecommunications Headquarters was reorganized, is responsible, with the three major British telecommunications manufacturers, for the development of System X.

He joined the British Post Office (BPO) in 1943 as a Youth-in-Training in Canterbury Telephone Area and much of his early career was concerned with developing new maintenance procedures and test equipment, particularly for improving the trunk network in preparation for subscriber trunk dialling. After this he worked for a period on the development of early reed electronic switching systems; later he became involved in the computerization of exchange specifications, and the early electronic exchange installation and acceptance-testing procedures.

Following promotion to Head of Division in 1969, he was mainly concerned with special studies for development of the telephone system; these included cost reduction of TXE4 and TXE2, use of multi-frequency signalling in the main network and CCITT/CEPT work on switching and signalling matters.

When, in 1974, the joint Post Office/Industry Advisory Group on Systems Definition came to the point where substantive development of System X could start, John Martin was appointed Deputy Director in the Telecommunications Systems Strategy Department, where he worked with Industry, starting the System X design and building up the development standards, processes, and teams for the System X project, a task which led naturally to his present appointment.

Institution of Post Office Electrical Engineers

General Secretary: Mr. R. E. Farr, THQ/NE/ NS4.1.3, Room S 04, River Plate House, Finsbury Circus, London EC2M 7LY; Tel. 01-432 1954.

(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the Oct. 1979 issue)

RESULTS OF THE 1979-80 ESSAY COMPETITION

Prizes and Institution Certificates have been awarded to the following competitors in respect of the essays named.

Section 1

Essays submitted by members of the Institution in all British Post Office (BPO) grades below the senior salary structure and above the grades defined in Section 2 below.

Prize of £10

Mr. J. B. Clark, Executive Engineer, Scottish Telecommunications Board HQ: *Engineering Management and the Eighties.*

Section 2

Essays submitted by BPO engineering staff below the rank of Inspector.

Prizes of £20 and an Institution Certificate

Mr. J. C. Duncan, Technical Officer, Reading Telephone Area: *The Problem with Cable Insulation.*

This is a very interesting essay giving a history of the development of cable insulation. The style enables the reader to move from one period of development to another in an easy manner and some enlightening background is added. The essay concludes with the introduction of the optical fibre cable, focusing on the ever present requirement to develop insulation properties commensurate with the growing demands on cables.

Mr. D. W. Lindsay, Technical Officer, Edinburgh Telephone Area: *Local Underground Maintenance.*

The author, in the early stages of his essay, introduces the key features of the local cable distribution network, and from this moves on to bring together experience since the introduction of polyethylene-type cables. Reference is made to the various stages in cable design and to the jointing techniques employed, and the essay is quite an eye-opener to the steps which have been necessary to keep polyethylene cables dry. The role of Repair Service Centres in cable maintenance is described, as well as the work and organization to locate blackspots in the local network. Obviously a lot of research has been put into the essay and the result is both interesting and a handy reference.

Mr. M. Wooldridge, Technical Officer, Bedford Telephone Area: *Buzby—A High Flyer for the Post Office.*

A fairly exhaustive treatment of the Buzby story from birth to the present day. Some interesting background is given to the direction taken by the Buzby campaign, together with some favourable indications of market trends since the introduction of Buzby. The author conducted some market research privately and includes a summary of his findings in the essay.

The prize winning essays are held in the Institution's central library, and are available to borrowers.

The Council of the Institution records its appreciation to Messrs. B. F. Yeo, G. W. Adams, A. H. Blois, M. E. Gibson and J. W. Gurr for undertaking the task of adjudication and providing summaries of the winning entries.

HONORARY MEMBERSHIP

The following have been elected to Honorary Membership in recognition of their considerable services to the Institution over many years:

Mr. J. F. P. Thomas, retired Chairman of Council.
Mr. C. E. Clinch, retired Vice-Chairman of Council.
Mr. K. E. Stotesbury, retired President of the Associate Section and Chairman of Stone/Stoke Centre.
Mr. A. F. Foster, retired Assistant Secretary.

THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)

A response to the IPOEE proposals from the FITCE Executive Committee is still awaited. If the proposal to allow certain members of IPOEE to join FITCE during a limited period without the usual academic or professional qualification is accepted, members will be given adequate notice of the time limit agreed.

CHANGES TO THE RULES OF THE INSTITUTION

Council has agreed the following Rule amendment.

Rule 58, amend to read:

An affiliation fee to cover administrative costs shall be paid to the Secretary of the Institution not later than 1 July each year. For those Local Centres which subscribe to the Associate Section National Committee, this Committee shall pay on behalf of all such Centres an annual bulk fee of £50. For independent Local Associate Section Centres, the annual fee shall be 1p per member.

R. E. Farr
Secretary

THE NEW TELECOMMUNICATIONS MUSEUM

A previous article† on the formation of the new Telecommunications Museum related the events which lead to the setting up of the museum. The opening date of the museum has been delayed until the end of March 1981 following a reassessment of the time scales involved. The curator now has the services of an historian, as well as those of the museum designer, to assist him in the layout of the museum. Particular items which the curator is seeking include parts and diagrams for a CB1 switchboard and for a complete working early UAX (formerly called RAX). He is also interested in finding pole tops, complete with arms, from an open-wire pole route.

One of the curator's tasks is to arrange for the restoration of items in the museum collection. He is, therefore, interested in compiling a list of people who have the facilities and interest to undertake such restoration work. The skills he is seeking include cabinet repairs, french polishing and bookbinding, as well as mechanical and electrical engineering. Transport of the items can be arranged. If anyone could help, please contact the curator on the telephone number given below.

† *POEEJ*, Vol. 72, p. 141, Oct. 1979.

As mentioned in the previous article, the curator is considering setting up a travelling museum which can be displayed at city festivals. He is now also considering the possibility of organizing the museum store in such a way that it will allow people with a more specialized interest access to those exhibits not normally on display.

The full postal address and telephone number of the museum have now been finalized and are: Telecommunications Museum, Baynard House, 135 Queen Victoria Street, London EC4V 4AT; telephone: 01-248 7444. Anyone intending to send items to the museum are asked to include their name and address, and if the items are large, to telephone the museum first.

Reference was made in the previous article to the possibility of a joint catalogue of items covering, if possible, all museums and museum stores within the British Post Office. To assist in this scheme, would anyone who has a museum or museum store please contact me on 01-357 2193.

J. M. Avis
Museum Liaison Officer

IPOEE CENTRAL LIBRARY

The books listed below have been added to the IPOEE library since the publication of the 1974 Library Catalogue. Any member who does not have a copy of the catalogue can obtain one on loan from The Librarian, IPOEE, 2-12 Gresham Street, London EC2V 7AG. Library requisition forms are available from the Librarian, from local-centre and Associate Section centre secretaries and representatives. The form should be sent to the Librarian. A self-addressed label must be enclosed.

5285 *Introduction to Microelectronics.* D. Roddy (1978)

This book describes the basic theory, construction and uses of semiconductors in integrated circuits and semiconductor memories.

5286 *Astronomy Data Book.* J. H. Robinson and J. Muirden (1979)

This reference book provides rapid access to up-to-date information on a wide range of astronomical matters.

5287 *Building Your Own Home.* M. Armor (1978)

All required information related to building your own home, plus a number of varied case studies, are described in this book.

5288 *Life on Earth.* D. Attenborough (1979)

This is a book based on the highly acclaimed television series about the development of life. Profusely illustrated in colour, it is a standard reference work for anyone interested in natural history.

5289 *Mathematics: An Introduction to Its Spirit and Use.* M. Kline (USA, 1978)

This is a lively and readable *Scientific American* publication which explores the scope of mathematics and its contribution to civilization and culture.

5290 *Evolution.* Scientific American (USA, 1978)

This is a bound reprint of the September 1978 edition of *Scientific American.* Its nine chapters outline different aspects of evolution from pioneering studies to the latest theories.

5291 *Programming Programmable Calculators.* H. S. Engelsohn (USA, 1978)

Written for those without any previous programming experience, this book is applicable to most programmable calculators using an algebraic operating system, specifically covering the Texas Instrument calculators SR52, SR56, TI57, TI58 and TI59, the Commodore PR100 and the APF programmable models.

5292 *Introduction to Microprocessors: Software, Hardware, Programming.* L. A. Leventhal (USA, 1978)

Reviewed on p. 126 of this issue of the *Journal.*

5293 *Radio and Television Servicing 1978-79.* R. N. Wainwright (1979)

This is the latest edition in this popular series, which gives servicing details for 1978-79 models of radios, televisions and record players.

5294 *Operational Amplifiers.* G. B. Clayton (1979)

This book gives comprehensive coverage of the subject for users or theoreticians, with reference to the increasing use of integrated-circuit amplifiers.

5295 *Videocassette Recorders.* G. P. McGinty (USA, 1979)

Videocassette recorders, which are now available as mass-marketed consumer products, are technically complex machines. This publication explains in simple terms how they work and demonstrates fault identification and correction.

5296 *Your Solar-Energy Home.* D. Howell (1979)

Written specifically for householders, this book gives practical examples of solar-heating systems for both domestic water and space, together with wind and methane schemes for power generation.

5297 *Safety Science for Technicians.* W. J. Hackett and G. P. Robbins (1979)

This book has been written specifically to cover the Technician Education Council syllabus in safety science, though it is equally suitable as a safety guide for technicians working in a laboratory or workshop. All common hazards are examined, along with practical safety suggestions and first-aid treatment.

5298 *Microprocessors and Microcomputers.* E. Huggins (1979)

Microprocessors are now so inexpensive that the limitations on their uses are no longer financial but lie in the ability of the user to understand their functions. This book assumes that the reader has no previous knowledge of the subject and explains development, operation and programming.

5299 *Signalling in Telecommunication Networks.* S. Welch (1979)

This IEE publication gives a comprehensive coverage of signalling principles and the concept of a complete network. It deals mainly with public telephone networks, examining both analogue and digital environments.

R. Cross
Librarian

The Associate Section National Committee Report

NATIONAL PROJECT COMPETITION

For this competition, centres are invited to enter any project completed by their members. Each entry is judged on its merits in accordance with the aims and interests of the IPOEE and the winning entrant is awarded the E. W. Fudge Trophy. The 1979 competition attracted 2 entries; a random-number generator from the London North West Centre and a quiz scoreboard from the Guildford Centre. The submitted projects were judged by our President, Mr. K. E. Stotesbury, and Mr. Bell, lecturer at the Technical Training College, Stone, who awarded the prize to London North West Centre.

In their report, the judges were somewhat critical of the attention paid to safety and documentation aspects of the respective projects. Of the random-number generator, the judges said that the designer had achieved what he had set out to do; that is, to produce a random-number generator which could be used by unskilled members of the public. Certain design deficiencies were highlighted in the design of the scoreboard; for example, the complex setting-up procedure and difficulties encountered when a positive number was subtracted from zero.

M. E. Dibden
Secretary

Associate Section Notes

CAMBRIDGE CENTRE

During the past year, the Centre has had a full programme which was well supported. Visits were made to a coal mine, the Royal Air Force establishment at Bedford, the British Post Office (BPO) Tower, the BPO underground railway, the Tewing Mill Trout Farm, Green King Brewery, Boosey and Hawkes, and the Ford Motor Company Ltd. Three talks were given during the year: one by our General Manager, Mr. A. Hull, on his work in the Cambridge Area; the others by two experts from the BPO Martlesham Research Centre on *Optical Fibre Systems* and *System X*.

The Interdepartmental General Knowledge Quiz took place during the winter period. Nine teams competed, and the winners were a team from Internal Construction, who will now go on to play in a challenge match against the Area Board and the Senior Section.

The annual general meeting was held in March and the following officers and committee were elected:

President: Mr. D. Ashman.
Chairman: Mr. G. Matheron.
Vice-Chairman: Mr. R. Plumb.
Secretary: Mr. P. Young.
Assistant Secretary: Mr. M. Sparham.
Treasurer: Mr. P. Gray.
Committee: Messrs. B. Matthews, R. Thorogood, M. Corby, P. Kerley and L. Salmon.

The programme for the coming year will consist of a hobbies-and-leisure evening, and visits to the Martlesham Research Centre, the United States Air Force base at Mildenhall, London Transport Underground Railway, London Weather Centre and Capital Radio. Details of these and other events will be circulated to all members. I hope that members will support all of the Centre's activities and make the 1980–81 session the best ever.

P. Young

EXETER CENTRE

Talks during the session included a very well attended illustrated talk given by Mr. T. Sage entitled *Over the Alps by Balloon*. Because of illness, it was necessary to find alternative speakers on two occasions and we are most grateful to the speakers who stepped into the breach at short notice. One of these was Mr. G. Cload who spoke on *Waterways and Barges*, illustrating his talk with slides of canals in the Midlands. Another talk undertaken at short notice was entitled *Forensic Science with Regard to Motor Accidents* by a member of the Exeter police. One of the best attended meetings was for Mr. J. Newman's lecture on *System X*. We were pleased to be able to afford Mr. Newman the opportunity to visit a measurement and analysis centre and thus make his journey an occasion for reciprocal information transfer.

Other subjects covered during the lecture programme included *Spark Ignition—Fact, Fiction and Fallacy; Model Railways* and *Solar Heating*.

In the National Technical Quiz, the South Western Regional final saw our team defeated by just half a point by Bournemouth.

J. J. F. Anning

LUTON CENTRE

The activities of the Luton centre continued to be successful during the winter period. Unfortunately, the visit to Corby steel works, which promised to be interesting, had to be cancelled because of the steel strike.

A visit to the London Transport underground depot in Acton in late January was much enjoyed by everyone who attended. During the visit the staff explained the various stages for completely stripping and refurbishing underground carriages. As well as bodywork and upholstery, the depot reconditions all mechanical parts, including the traction motors.

In February, by popular demand, local member Ken Drew gave another talk, which on this occasion was entitled *How a Steam Engine Works*. During the talk, Ken used a model steam locomotive that he is building to demonstrate the operation of various components.

Our much postponed hobbies evening was eventually held in the middle of March. Among the exhibits on show were Dinky toys, radio-controlled gliders, model railway items, glass decanters, examples of caligraphy, details and photographs of walking holidays, a small printing press, and a home computer. The exhibition provided members with an opportunity to look at other people's hobbies, and we will try to repeat it in the future.

The annual general meeting was held in April of this year.

Unfortunately, our chairman, Mick Wooldridge, and our treasurer, Barry Wheeldon, did not seek re-election this time. The committee would like to thank Mick and Barry for their several years of excellent service in the Luton centre.

P. OSBORNE

OXFORD CENTRE

The Oxford centre has enjoyed moderate success in the National Technical Quiz. Nottingham were beaten in a land-line quiz which put us forward to the quarter-final, where we were drawn against Londonderry.

Londonderry requested a face-to-face confrontation, like the one that we had had previously with Guildford Associate Section, and arrangements were made for the visit to Londonderry.

Our whistle stop tour began with a short drive to Heathrow airport, where we boarded the British Airways shuttle service. On arrival at Aldergrove we were met by Mr. Joe McDonnell and driven along the scenic coastal route to our hotel. The Londonderry team had arranged a land-line to Oxford for the benefit of our supporters. After an extremely tense high-scoring match, we emerged victors by 4 points.

Our tour concluded with visits to a TXE4A exchange and the Belfast main exchange, before we stopped for an excellent lunch provided at the British Post Office Training School at Fort William Park. Afterwards we were treated to a delightful guided tour of the school's impressive facilities.

We would like to take this opportunity to thank all those people involved in the Associate Sections in Northern Ireland for a stimulating competition and for extending their hospitality to us.

In March we were drawn against Bradford in the semi-final of the quiz. The Bradford team were invited to Oxford for the competition; when they arrived they were met by 2 of our members who gave the team a brief bus tour of the University. At the end of all the questions both sides had scored 42 points. Eventually the Oxford team won the tie-breaker with their answer to a question on complementary metal oxide semiconductors.

C. H. HUGHES

SWINDON CENTRE

At the annual general meeting of the Centre, the following officers were elected:

Chairman: Mr. W. Baker.
Hon. Secretary: Mr. W. G. Hacker.
Hon. Treasurer: Mr. P. King.
Visits Hon. Secretaries: Mr. T. Harris and Mr. A. Carter.

Unfortunately, Mr. A. Hawkins, the previous Honorary Secretary was unable to stand for office because of other commitments.

During the session, a very interesting lecture on inland waterways was given by the chairman of the local canal restoration society. Visits were arranged to the BBC at Bristol, the Avon Rubber Company, a Magnox nuclear power station, a coal mine, RAF Lyneham and Vauxhall motors.

W. G. HACKER

Post Office Press Notice

POST OFFICE BACKING FOR OPTICAL-FIBRES RESEARCH

The British Post Office (BPO) has given British research into optical communications a major boost by providing financial backing for a Chair of Optical Communications at Southampton University. The holder of the new post, to be known as the *British Telecommunications Chair of Optical Communications*, is Professor Alec Gambling, D.SC., PH.D., F.ENG., F.I.E.E., former head of the University's Department of Electronics. At the same time, Dr. John Midwinter, PH.D., B.SC., C.ENG., F.I.E.E., M.I.E.E.E., M.INST.P., head of optical communications studies at the BPO's Research Centre at Martlesham, has been made a visiting professor at the University.

The BPO will provide financial support to cover the Professor's salary and ancillary expenses for an initial period of 5 years; the BPO may also finance specific research projects. However, the university will be free to continue to seek funds for research in the usual way from such institutions as the Science Research Council, Industry, and the Ministry of Defence.

Although the precise topics of research will be under the direction of Professor Gambling, and will depend on the development of the subject, they are expected to include optical-fibre fabrication, propagation, instrumentation, and a study of applications, especially in telecommunications.

Apart from his work at the university, the Professor will spend at least 2 weeks of each year at the BPO's Research Centre, or elsewhere as appropriate. During this period he will act as a consultant, in order to become fully acquainted with the BPO's work on optical communications and to point out new areas of work that might be profitably exploited. He will thus be able to feed back information to the BPO not just about university work but also about world activity generally in this field.

Announcing the creation of this new Chair, John Whyte the BPO's Deputy Managing Director: Telecommunications, anticipated that it would give added impetus to the University's work on optical communications, and form the basis for a joint BPO-university research and development programme. He felt that this would promote the long-term interests of British telecommunications and of the BPO, whose customers would benefit not only directly, but also indirectly, through the stimulation of exports. Finally, he believed that the new Chair would provide a focus for co-operation between the BPO and Southampton University, and encourage exploitation by the BPO and British Industry of the original work carried out at Southampton.

INDEX TO ADVERTISERS

Advertisements

Communications, advertisement copy, etc., should be addressed to Mr. N. G. Crump, The Advertisement Manager, POEEJ, Room 506D, 2–12 Gresham Street, London, EC2V 7AG (Tel: 01–357 2089).

No responsibility is accepted by the Journal for any of the private or trade advertisements included in this publication.

The Post Office Electrical Engineers' Journal

Copyright

Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 70p per copy (£1·05 per copy including postage and packaging); annual subscription: £4·20; Canada and the USA: $10·00.

The price to British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 70p (£1.05 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975 issues; copies of the July 1970 and April and October 1973 issues are also still available.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £5·25, including return postage, by sending the complete set of parts, with a remittance, to Press Binders Ltd., 4 Iliffe Yard, London SE17 3QA.

Remittances

Remittances for all items (except binding) should be made payable to "*The POEE Journal*" and should be crossed "& Co."

Advertisements

All enquiries relating to advertisement space reservations, copy, proofs, etc. should be addressed to Mr. N. G. Crump, The Advertisement Manager, *Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG (Telephone: 01-357 2089).

Distribution and Sales

Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG.

Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NE/P12, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY (telephone 01-432 4840).

Model-Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Sales Department, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG, and printed in Great Britain by Unwin Brothers Limited, The Gresham Press, Old Woking, Surrey

the sealectro connection

The Sealectro range of products include: RF Coaxial Connectors, Flexible and Semi-Rigid Coaxial Cables, Insulated Terminals, Cable Assemblies, PCB Components and plugboard systems.

Sealectro Limited, 1980.

CONHEX 75Ω COAXIAL CONNECTORS SELECTED BY THE POST OFFICE FOR TEP.1.E USE

Sealectro 75Ω connectors have been selected by the Post Office for use with TEP.1.E and will carry the new designation Type 43– Series. The range was chosen as offering the best price-performance combination. As well as meeting a stringent technical specification, the cost considerations of the equipment manufacturers were carefully observed.

The primary application will be in digital telecommunication systems as the critical coaxial interconnection. The range has previously been used in PCM systems and submarine repeater stations as well as instrumentation and measurement applications.

Type 43– Series will comprise the range of connectors covered by the tabulation. Engagement of the plugs and sockets can be of standard "Snap-on" construction or the "Posi-Lock" method which is likely to be the preferred method in the majority of applications.

"Posi-Lock" is a unique Sealectro development with a latching mechanism designed to prevent accidental disengagement of the connection, yet facilitate easy disconnection as required.

The additional facility of a Coaxial 'U' link, compatible with the new range, will also be available. Designated Type 13A, the 'U' link will have a superior performance capability ensuring minimal degradation of system electrical requirements.

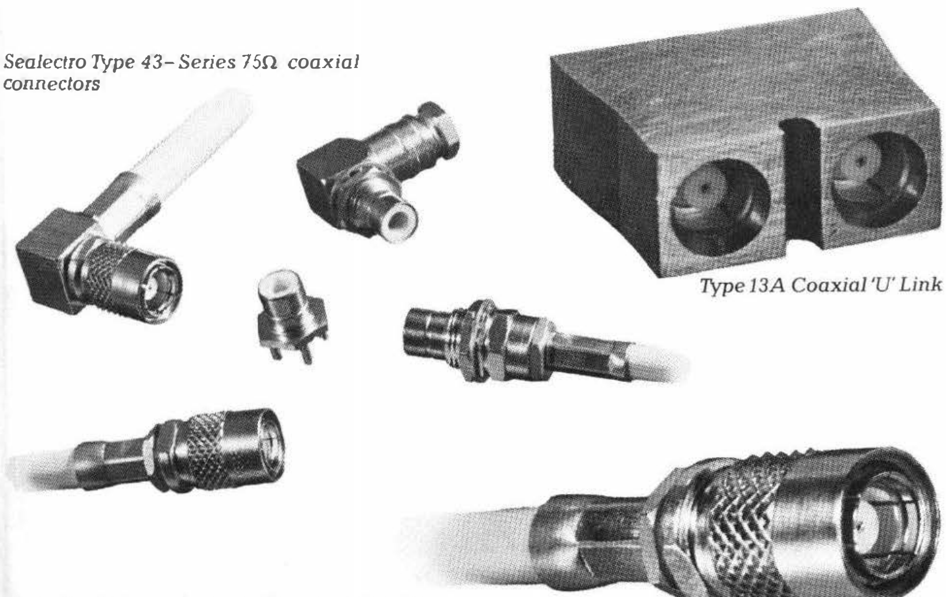
For general information consult the standard Conhex catalogue in conjunction with the tabulation shown here. A full Technical Performance Data Sheet will be available later but for current enquiries call Sealectro.

PLUG COAXIAL 43/– – –

Suffix	Type	Cable	Sealectro
1A	Straight Bulkhead (STD)	2001	51-127-9219
2A	Straight Bulkhead (STD)	2002	51-127-9229
3A	Straight Bulkhead (STD)	2003	51-127-9239
4A	Straight Bulkhead (STD)	RG 179	51-127-3187
1B	Rt. Angle Bulkhead	2001	51-130-9219
2B	Rt. Angle Bulkhead	2002	51-130-9229
3B	Rt. Angle Bulkhead	2003	51-130-9239
4B	Rt. Angle Bulkhead	RG 179	51-130-3187
1C	Straight Bulkhead 5mm	2001	51-127-9269
2C	Straight Bulkhead 5mm	2002	51-127-9279
3C	Straight Bulkhead 5mm	2003	51-127-9249
4C	Straight Bulkhead 5mm	RG 179	51-127-9299
1D	Straight PWB Mounting		51-151-9019
1E	Rt. Angle PWB Mounting		51-153-9029

SOCKET COAXIAL 43/– – –

Suffix	Description	Cable	Sealectro
1A	Straight Free (STD)	2001	51-124-9269
2A	Straight Free (STD)	2002	51-124-9279
3A	Straight Free (STD)	2003	51-124-9289
4A	Straight Free (STD)	RG 179	51-124-3187
1B	Straight Free (Posi-Lock)	2001	51-124-9219
2B	Straight Free (Posi-Lock)	2002	51-124-9229
3B	Straight Free (Posi-Lock)	2003	51-124-9239
4B	Straight Free (Posi-Lock)	RG 179	51-124-9249
1C	Rt. Angle Free (Posi-Lock)	2001	51-128-9219
2C	Rt. Angle Free (Posi-Lock)	2002	51-128-9229
3C	Rt. Angle Free (Posi-Lock)	2003	51-128-9239
4C	Rt. Angle Free (Posi-Lock)	RG 179	51-128-9249



Sealectro Type 43– Series 75Ω coaxial connectors

Type 13A Coaxial 'U' Link

Type 43– Series socket with 'Posi-Lock' latching mechanism

sealectro

Sealectro Limited, Walton Road,
Farlington, Portsmouth,
Hants, P06 1TB, England.
Tel: Cosham (0705) 373211
Telex: 86142

Clip this coupon to your letterhead and send to the above address.

☐ Please send me your Conhex Catalogue and put me on your mailing list for the Technical Performance Data Sheet.

☐ Please arrange for a Sealectro representative to contact me.

Name:

Position:

NEW

"DIGICOUNT"/MF4

"DIGICOUNT"/MF4 is a hand held, battery operated tester supplied in the same package as "DIGICOUNT" (See opposite page).

"DIGICOUNT"/MF4 is uniquely designed so that the unit decodes and displays all the 16 DTFM codes as dialled, with full LED Alpha-Numeric display as illustrated below reading from left to right.

1 2 3 4 5 6 7 8 9 0 * + A B C D

Actual display size

"DIGICOUNT"/MF4 has selectable AUTO/NON-AUTO/MANUAL RESET. Guard times, input sensitivity and other operating parameters will be agreed to meet customers requirements prior to delivery.

For further information please contact:

area intertrade limited AIL

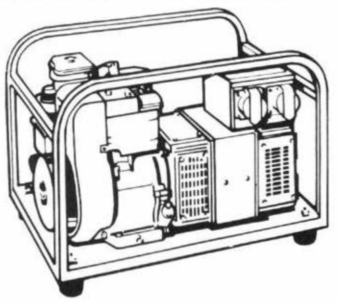
34 LOWNDES STREET, LONDON, SW1X 3HX
TELEPHONE: 01-245 9477/9. TELEX: 914142 CLTRAD G.

Instant Portable Power

The three features you look most for in generators – durability, reliability and economy, can all be found in the Erskine range of generator systems. And we've paid particular attention to each.

Choose from petrol, bottled gas and diesel systems all carefully designed and stringently checked for a long, profitable, dependable life.

Phone now for further information.

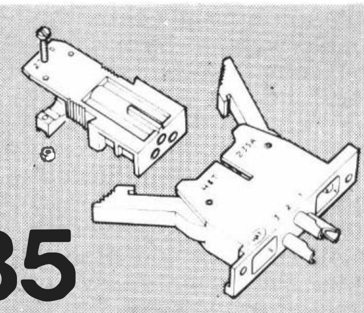


ERSKINE

Erskine Systems Ltd, Scarborough, North Yorkshire, YO11 3DU. England. Tel: 0723 583511. Telex: 52562.

A member of the DALE group of companies.

The new P.O.235 Connector



Designed specifically for TEP 1 (E) equipment practice. The 235 is compatible in appearance with I.D.C.'s and is ideally suited as a low cost high spec. 3 pole power connector.

Features include:-
- Single Contact Rating 15A
- Connector Rating 10A
- Contact Resistance <5m Ω
- Wire Range 0.1 to 1.5sq.mm.
- Crimp/Solder Poke Home Contacts
- Polarised shells
- Double lock retention

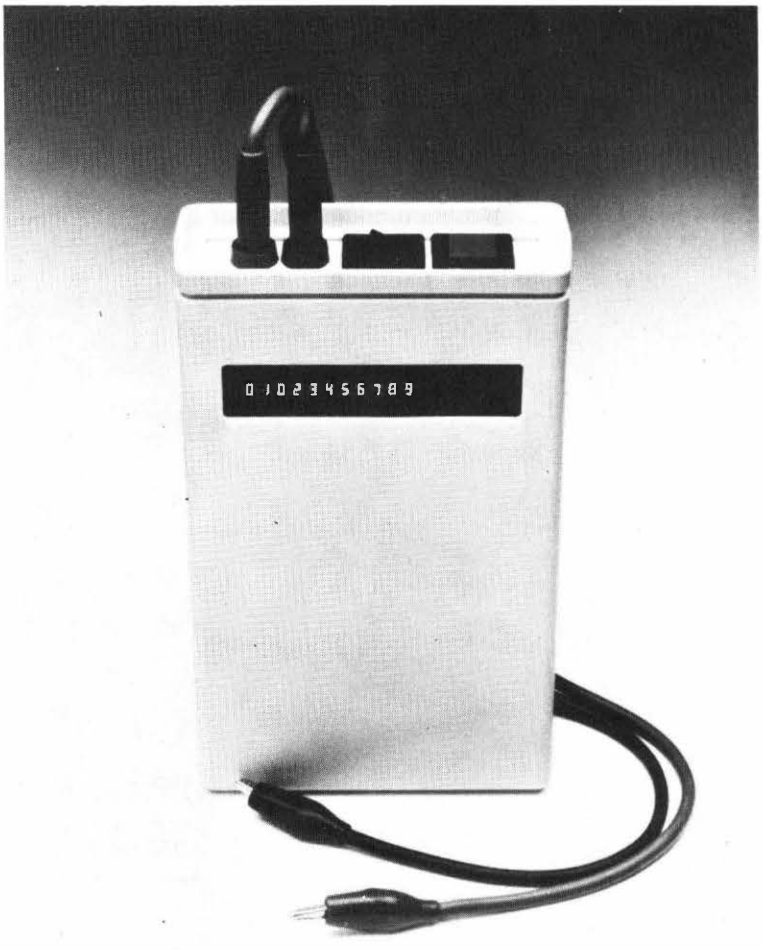
For Data and Samples Contact

H & T COMPONENTS LTD

Crowdy's Hill Estate, Kembrey Street, Swindon, Wiltshire
SN2 6BN Tel: Swindon (0793) 693681-7 Telex: 444166

H & T also manufacture the following P.O. approved connectors 'U' Link 32A, Co-Axial Links 10C, 10D & Mounting D79552. For your special requirements contact H & T Special Products Division

"DIGICOUNT"



"DIGICOUNT" is a compact, hand held, self powered, robust, simple to use unit for counting LOOP DISCONNECT PULSES to POST OFFICE LINES, where the number dialled is displayed on a sixteen digit LED display driven from internal CMOS devices.

APPLICATIONS include confirming outputs from:–

- ★ PRE-PROGRAMMED DIALLERS
- ★ AUTOMATIC CALL MAKERS
- ★ VIEWDATA/PRESTEL TERMINALS
- ★ EXCHANGE EQUIPMENT
- ★ DOMESTIC TELEPHONES
- ★ SHORT CODE DIALLING SYSTEMS
- ★ MODEMS

"DIGICOUNT" incorporates an input circuit specifically designed to overcome the problems associated with mechanical type relay derived pulses, coupled to long lines which generate large voltage swings and have inherent contact bounce and drop out. The input impedance exceeds the open loop requirement, which is in excess of 5 MEGOHM, thus there is effectively no loading under test, this is achieved by a combination of Schmitt triggering and integration filtering followed by digit counting and interdigital pause detection by a unique patented counter which allows for large changes in dial speeds, this is then fed to an internal memory which is multiplexed to drive the sixteen digit display reading from left to right.

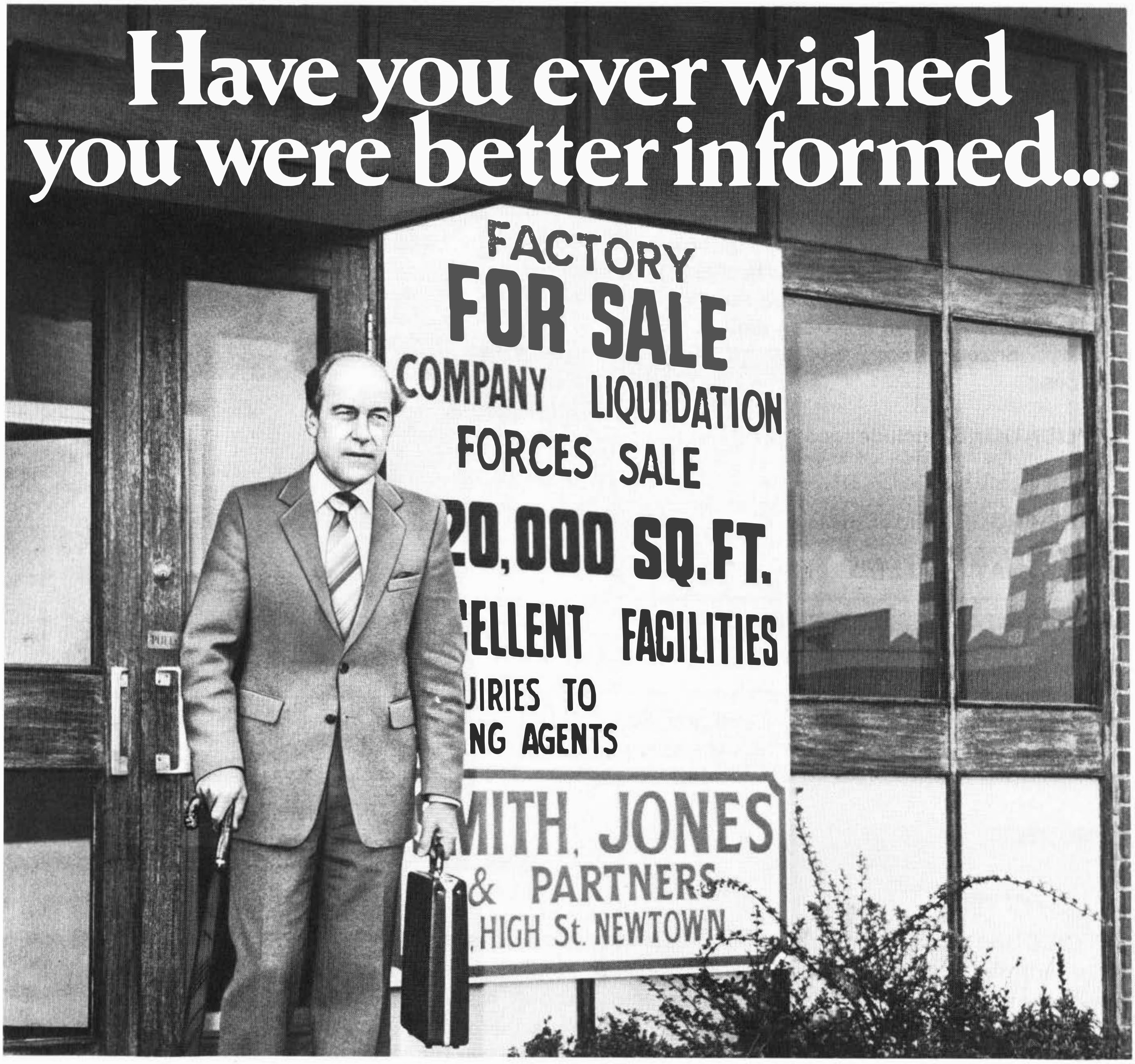
"DIGICOUNT" is pre-tested and adjusted prior to delivery to work on 10 cycle, 16 cycle and 20 cycle systems without modification where the line voltage is 50 volts and allows for the nominal voltage drop. Variations on this specification are by request.

"DIGICOUNT" is delivered in a black leather case and comes complete with test leads. The unit is powered by 4 x 1.5 volt batteries, type AA size.
DIMENSIONS:— 155mm x 90mm x 34mm, DESIGNED AND MANUFACTURED IN THE U.K.

For further information please contact:–

area intertrade limited AIL

34 LOWNDES STREET, LONDON, SW1X 3HX
TELEPHONE: 01-245 9477/9. TELEX: 914142 CLTRAD G.



...about microprocessors?

2000 leading companies already are, having purchased the Open University's new package of learning materials **Microprocessors and Product Development: A course for industry.**

The astounding growth of 'chip' technology makes it imperative that your company doesn't get left behind. Microprocessor technology will bring complex and far-reaching changes, even for those companies producing everyday items. Those who don't keep up will face a bleak future, if any at all.

This specially prepared Open University course is particularly for those who have to advise on new product development, including management in financial, personnel, product-planning and marketing areas.

It explains in layman's language just what microprocessors are, how their technology is applied, and what is involved in producing a microprocessor-based product.

It links the Open University's skills in preparing independent learning materials to the best available technical expertise. The package includes all you need, with your own microprocessor, instruction manual, work material and six detailed booklets.

At the current price of £120, **Microprocessors and Product Development** is a competitively priced self-study package. It is completely up-to-date and is available now for you to start at any time. You work at your own pace, when and where you like - or you can use it in your own in-company training scheme.

Complete and post the coupon today. You just can't afford to be left behind.

To: The Open University, PO Box 188 (MPO) Milton Keynes, MK3 6HW.
Please send me further details of Microprocessors and Product Development: A course for industry.

Name ____________________

Company ____________________

Address ____________________

____

MAP 4

THE OPEN UNIVERSITY

The Open University, PO Box 188 (MPO) Milton Keynes, MK3 6HW.