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EDITORIAL

This year, 1986, has been designated *Industry Year 1986*. Industry is fundamental to almost everything that happens in the UK, yet industrial activity is held in low social esteem. The aim of Industry Year 1986 is to encourage a better understanding of industry, its essential role, and its service to the community, and to win acceptance for it. The most important area where a long-term change in attitudes can be achieved is in education, and much effort is being directed towards this goal. In the short-term, however, it is necessary to increase the public awareness of the vital role of engineering in society and to demonstrate effectively the direct and beneficial impact good engineering has on everyday life. The quality of a product or service is just one area in which the application of engineering skills can benefit not only the customer, but also the manufacturer or service provider. This is discussed in an article on p. 216 of this issue of the *Journal*.

RATES: An Aid to Private Circuit Testing

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UDC 621.395.12.001.4

British Telecom is currently introducing remote test capability into its extensive analogue private network in order to improve fault localisation efficiency and so reduce overall repair times. This is being accomplished by the development of a remote access and test equipment system (RATES) which enables testing staff to gain rapid access to circuits without the need for manual intervention at exchange locations en route. Benefits include faster and more co-ordinated testing of circuits, reduced travelling time with consequent reductions in circuit down-times.

INTRODUCTION

Private circuits form an important part of British Telecom's (BT's) network services. Used by business customers in the main, they carry a varied range of traffic from speech and telemetry through to high rates of data. Table 1 lists some of the main applications. A characteristic of private circuits is their exclusivity to the customer concerned. Whilst sharing common line plant and routeings with switched services, they do not pass through switches themselves, and are effectively 'hard wired' through the network. There are currently some 55 000 long-distance private circuits in the UK (that is, circuits which are routed through the national trunk transmission network) with approximately half a million short-distance types.

The maintenance of such circuits presents its own particular difficulties, and BT is anxious to further improve the performance of these services in terms of minimising circuit down-times caused by faults. Progress has been made in recent years on two major fronts, these being the administration of circuit maintenance, and the facilities for circuit testing. This article confines itself to the latter where significant developments have taken place with the introduction of remote testing of private circuits by using a system called *remote access and test equipment system* (RATES). Such a system provides faster, more accurate and co-ordinated testing of circuits, and hence more efficient localisation of faults when they occur. Currently, the system is geared to accessing and testing circuits which are analogue presented. This is still the most common form of presentation. Developments are under way to provide similar facilities for circuits which are digitally presented.

TABLE 1
Applications for BT Private Circuits

Point-to-point speech circuits
Point-to-point and multipoint data circuits
Inter-PBX circuits for customer networks
External extensions
Alarm and telemetry circuits
Out-of-area exchange lines

TESTING PRIVATE CIRCUITS

Apart from the initial commissioning of private circuits before they are handed over to customers, most testing activity is associated with fault diagnosis and localisation. Historically, faults on private circuits have often taken longer to rectify than those on public switched circuits. This has largely been a result of the diversity of circuit routeings and the economic difficulties of providing the specialised test equipment and staff needed to diagnose the more complex faults that can occur. The hard-wired nature of the circuit means that there is no method of interception for testing *en route* other than by manual means, and staff often have to travel to unattended exchanges to test a faulty circuit. Co-ordinated testing between two points on a circuit further compounds the difficulties. Because of the wide range of signals carried by such circuits, standard tests using readily available equipment are not always sufficient to resolve quickly any faults encountered. Data customers can be particularly sensitive to circuit impairments owing to the lower redundancy of data signals compared to speech. On speech applications, a multiplicity of signalling systems can be encountered, and these need to be accommodated in any testing that is carried out.

It is against this background that BT decided some years ago to adopt the philosophy of siting purpose-built automatic circuit access and specialised test equipment at strategic interception points in the network and remotely controlling them from manned test centres. This concept was encouraged by experience gained by the North Americans in private circuit testing using a similar technique. In this way, the skilled testing staff would be concentrated and more efficiently used. There would be less need for time-consuming site visits, and, because a single test operator could have access to more than one point on a circuit simultaneously, there would be improved test co-ordination. RATES was developed around this philosophy.

RATES ARCHITECTURE

The architecture of RATES is shown in Fig. 1 and comprises two main system elements:

(*a*) *test access equipment* (TAE) sited at telephone exchanges through which private circuits are routed, and

(*b*) *central test facility* (CTF) sited at a convenient point where testing staff are located.

Private circuits are accessed at telephone exchanges and routed through the TAE. While TAEs could theoretically be placed in every exchange, it is normally economic at present to place them only where there is a concentration of 50 or more private circuits routed through an exchange. A single CTF is normally adequate for an average Telephone Area and it will have remote control links to every TAE in that local area.

The TAE has the capability of accessing any private

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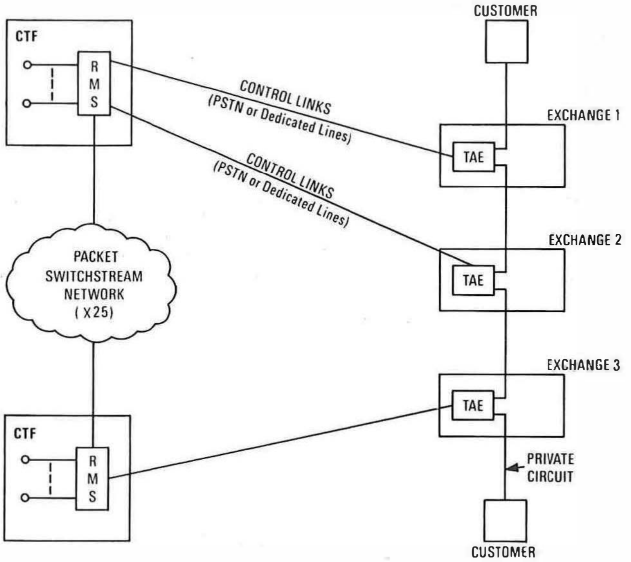

Fig. 1—RATES architecture

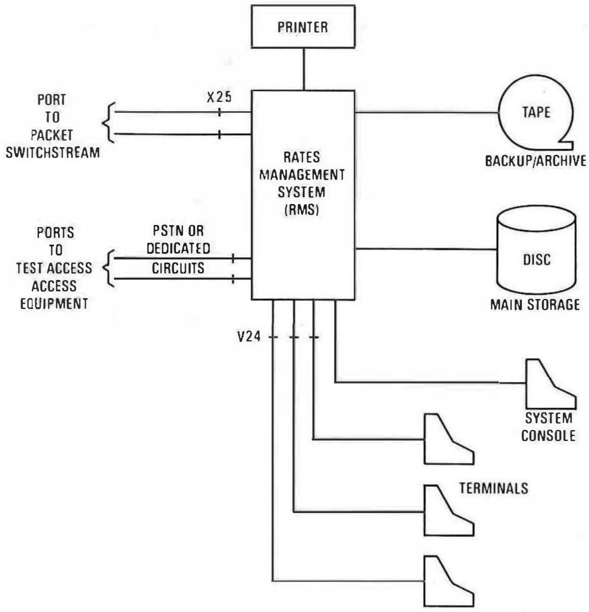

Fig. 2—CTF architecture

circuit routed through an exchange and applying or measuring test conditions at that point. This action is performed under remote control from the CTF. Thus, an operator at a CTF can remotely carry out tests at points on a circuit routed through the local area and, in particular, can coordinate testing between two points by controlling two TAEs from a single test terminal. If the operator needs to test a circuit at other points which are not within the local area, this can be accomplished over communication links with other CTFs.

CENTRAL TEST FACILITY

The CTF is the operator's interface with RATES; therefore, its design and capabilities play a major role in the smooth transition from the traditional test and maintenance procedures to the new remote access and test philosophy. Consequently, careful consideration was given to the design of the CTF, and in particular, the man–machine interface. The CTF provides a simplified man–machine interface and controls the functions of the TAE in response to operator commands. It holds the database for TAEs, circuits and test points within its local area and it controls the use of communications to TAEs and other CTFs.

A simplified architecture of a CTF is shown in Fig. 2. The hub of a CTF is a computer known as the *RATES management system* (RMS). The RMS will typically support 12 local or remote visual display terminals, a printer at every terminal site, PSTN or private-circuit communication links to its local TAEs, Packet SwitchStream (PSS) X25 links to other RMSs and a database, which can be expanded from 60 Mbytes to several hundred megabytes.

The man–machine interface was designed in a way which allows the operator to concentrate on the testing required for localising and identifying faults on private circuits. The operator does not need to be aware of how the test equipment is being controlled, how communications to the TAEs are established or cleared down or how the relevant information is accessed, be it from the local database or from any other remote database via the PSS links. For instance, test-tone instructions can be given in dBm0 and the system automatically corrects for absolute levels by using information on relative levels stored in the database. To assist in the fault identification process, the user has access to circuit record and fault history information from the database; this is discussed in greater detail below.

Once an operator has logged on to the RMS, the testing is carried out by selecting labelled softkeys which are displayed on the screen. Each softkey is labelled according to the type of function or facility it provides and, by selecting one softkey, a further and more detailed selection is presented to the operator. By means of this step-by-step process, individual tests or functions are identified, usually within three to five keystrokes of the highest level in the dialogue, and executed. With experience, operators can by-pass the step-by-step procedure by stringing together several softkey selections rather than waiting to be prompted by the RMS at each step. A facility is available to store a string of softkey sequences for later recall by any operator.

During a typical session, the operator indicates the circuit to be accessed by selecting the appropriate softkeys, together with the circuit designation. On receipt of this information, the operator's terminal displays the circuit record card (see Fig. 3). The record card contains customer and circuit detail, a brief schematic representation, circuit end-point data, and information on each RATES test point along its route. The test points can then be accessed individually, or all together, by selecting the appropriate softkey. The test-format screen is displayed and the selected test points are accessed by establishing a data link to the TAE in which an access is to

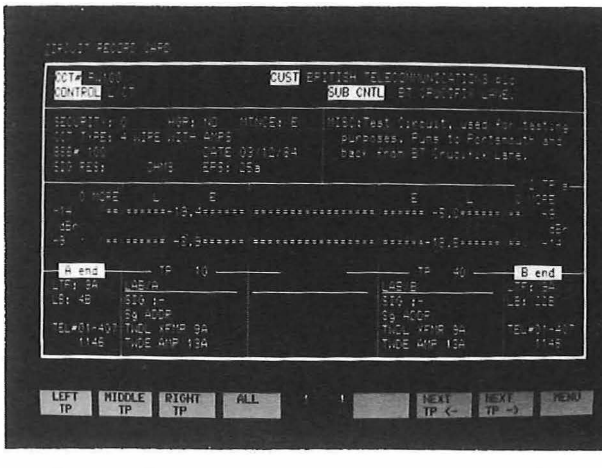

Fig. 3—Circuit record card

be made. Up to two test points can be displayed schematically on the terminal screen, the others being kept in store, and transferred onto the screen as required. Once communication with all the requested test points has been established, the testing phase can begin.

As an example, the operator can apply a test tone at one point and measure the transmission level at other points along the circuit. The operator can then temporarily loop the circuit (if 4-wire) at either, or both, of its end points, if the appropriate terminal equipment is installed, to check transmission levels around the loop. If the circuit is used for speech and makes use of signalling protocol for call control (for example, AC13 for inter-PBX circuits), the operator can talk to the customer via the private circuit, and carry out some signalling system checks. Because of the quantity of different signalling protocols used on private circuits, and in some cases their complexity, the RMS is designed to automatically implement the correct signalling protocol when the operator selects signalling softkeys such as CALL CUSTOMER. The screen format during a typical test sequence is shown in Fig. 4. At any time during testing or on completion, the operator can display or print out a log of all tests and test results for the accessed circuit.

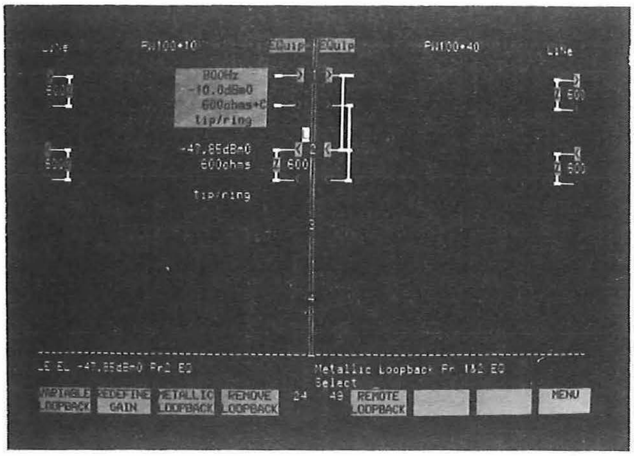

Fig. 4—Testing screen format

In order to carry out circuit testing in the way described where no information is required from the operator other than the circuit designation, a database of circuit and network information must first be established. This database must include:

(*a*) circuit specific details (for example, number of circuit pairs, type of signalling, location of test points),

(*b*) TAE hardware configuration (test points allocated to circuits), and

(*c*) network related information (for example, identity of all other CTFs, other CTF databases which contain further test point information for circuits which pass outside the local area, etc).

This requirement involves a major data collection and entry exercise to establish the database. However, as a result of this work, several essential tables and forms can be generated by the RMS to assist in the introduction of TAEs into the private circuit network and for its day-to-day running. For example, schedules can be printed out on a TAE basis to indicate how the exchange distribution frame must be re-wired in order to route circuits via the TAE. TAE spare capacity information can be displayed so that at any time the system manager can determine how many access points are available for future use. Other valuable facilities provided by the RMS include a TAE diagnostic package for localising TAE hardware faults down to board level, and a training package which allows new operators to familiarise themselves with the access and test dialogue. Fig. 5 shows a typical CTF environment.

Fig. 5—Typical CTF environment

TEST ACCESS EQUIPMENT

The functions performed by the TAE can be split into two main sections. The first is to provide a reliable fail-safe and secure access switch block through which the private circuits are routed. Secondly, to provide remote access ports (RAPs), which contain the remote test equipment together with the communication interfaces to the CTF.

The access switch block is modular in construction and is technically capable of expansion from one circuit to tens of thousands of circuits. The switch incorporates high-quality relays capable of meeting the unusual demands of long life with infrequent operation.

When the required circuit is accessed, it is temporarily re-routed to the RAP for the duration of the access (see Fig. 6). During the access process, a check for continuity of

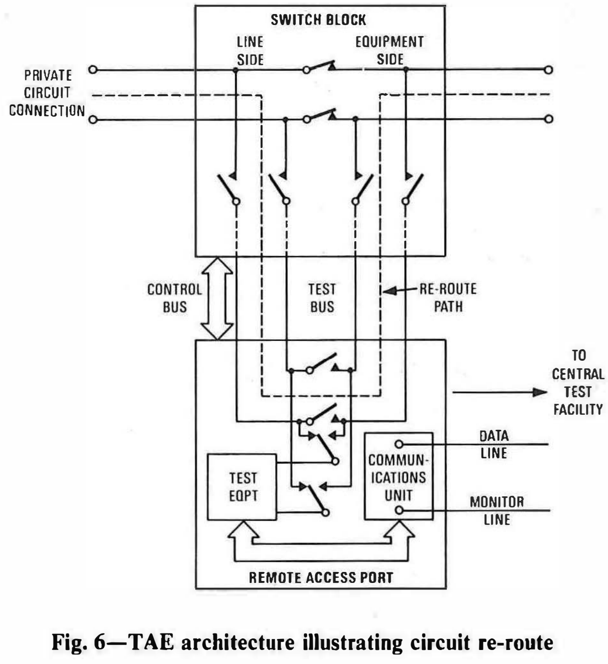

Fig. 6—TAE architecture illustrating circuit re-route

the re-route path is made prior to the circuit being diverted. Upon successful completion of the access, the circuit is connected to the RAP and then tested under the command of the CTF operator.

Facilities

Some of the many facilities available are detailed below.

Monitoring

This provides a high-impedance connection across the accessed circuit to the operator's monitor circuit.

Splitting and Terminating

This facility splits the circuit, terminates all ports with the impedance defined within the circuit database; it also conditions the circuit pairs with signalling and DC potentials normally present on the circuit.

Multimeter Functions

These include the ability to measure capacitance, resistance, voltage and current.

Signalling

This facility allows the operator to exercise the various signalling conditions necessary to establish a call on the circuit under test, and communicate with the customer over the circuit via the monitor facility. The RATES system covers as many as 14 different signalling systems including automatic and manual types. The following are just a few of the signalling systems covered: Loop, MF4, AC13, AC15 and DC10.

Transmission Facilities

These include sending single-frequency tones within the audio spectrum at selected levels and the measurement of frequency and level (either wideband or selective). Also available is the capability to measure 'noise' with various filters; for example, psophometric weighting.

External Instruments

This facility allows the circuit under test to be transferred to auxiliary IEC† 625-controlled test instruments. This facility is valuable where more specialised testing is required at particular TAEs only. Group delay measurement is currently being considered as well as tests for data affecting parameters, phase and gain hits, drop outs etc.

These instruments are controlled by software in the CTF via the normal link between the TAE and the CTF.

Control Functions

The TAE has the capability of sending the appropriate control signal to activate an automatic loopback device connected to the circuit under test. An additional function is the ability to transfer the circuit under test to a dedicated data test centre.

COMMUNICATION AND SECURITY

Owing to the large number of TAEs in each CTF local area and the relatively large number (up to 30) of CTFs which are networked together to provide an end-to-end testing capability on a national level, much of the data communication is based on switched networks.

The PSTN is the most economic means of communication between the CTF and TAEs when the quantity of TAEs and the level of activity on any one link is considered. The PSS service was chosen to link CTFs (that is, between RMS computers) because of its fast call set-up time, its inherent rerouteing capability and suitability for bursts of high rate data.

If an operator wishes to access the CTF's local area, then the RMS will instruct its auto-dial modems to establish a data channel to the relevant TAE. If, however, the test point is in a TAE in some other CTF's local area, then the RMS will, via the PSS service, pass instructions to the distant RMS to communicate with the TAE and carry out the testing.

Security against unauthorised access has been a prime consideration in the system design. In addition to the first-line security facilities of user name, password and capability classifications for user log-on, a second-level system password between CTF and TAEs is incorporated and this is encrypted over the communication link with the TAE.

Operators are unaware of the encryption taking place and transfer of TAE caller authentication data is carried out automatically so that only the local CTF manager need know the passwords and keys, which are changed on a regular basis. Security of communication between RMSs is provided by the use of a closed user group over the PSS service and a calling party identification procedure.

COMPATIBILITY

With BT's commitment to competitive tendering and for allowing different manufacturers to design and supply TAEs, the interface between the RMS and the TAE has been standardised. The benefit of this approach allows the user interface at the CTF, together with the RMS software and hardware, to be the same irrespective of the TAE manufacturer. Currently BT is procuring TAE equipment from two manufacturing sources.

Consideration is currently being given to ways in which the RMS computer can inter-communicate with other BT computer systems in the circuit maintenance and provisioning field.

BENEFITS OF RATES

The benefits of the RATES system can be broken down into two areas: improved features and reduced costs.

Improved Features

These can be summarised as:

- faster fault localisation,
- remote testing at unmanned exchanges,
- reduced testing time,
- better testing co-ordination,
- minimum of abortive visits to unmanned exchanges,
- reduced out of service time,
- faster retrieval of records, and
- more efficient use of skilled staff.

Reduced Costs

Savings are made by:

- eliminating manual jackfields,
- reducing the need for manual test desks,
- minimising the cost of visits to exchanges, and
- reducing the duplication of records.

† IEC—International Electrotechnical Commission
IEC 625 is the international standard interface bus for test equipment

IMPLEMENTATION

The implementation of the RATES system into the BT network has progressed from an extensive field trial at a large conurbation in the UK to the full implementation of the system on a national basis. Fig. 7 shows a typical TAE installation with a capacity of 5000 circuits. The main impetus of this implementation is to connect retrospectively existing circuits as well as new circuits. The connection of existing circuits has required an extensive data collection exercise of the data required for both the system database and interception of the circuits.

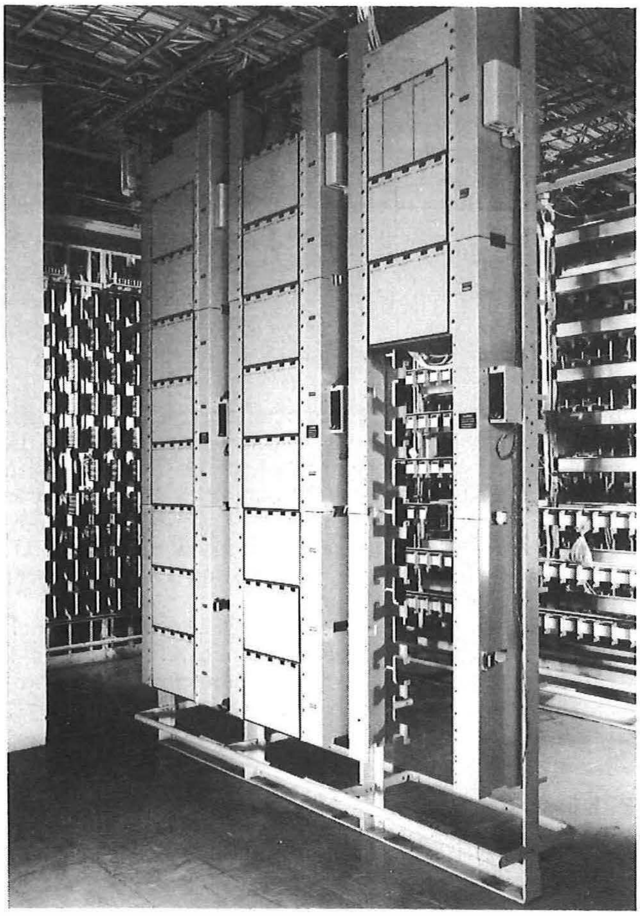

Fig. 7—Typical TAE installation

TAEs to BT's technical performance and facilities specification are currently being developed by Plessey Telecommunications Ltd. and Hewlett Packard Ltd., which is also developing the CTF.

FUTURE

Several possible applications for RATES on other BT networks are currently under consideration. These include testing of KiloStream circuit local ends, test access at KiloStream cross-connection sites via automatic cross-connection equipment (ACE)[1] and testing of LinkLine circuits.

CONCLUSION

RATES is being installed on a national basis to increase the efficiency of testing and maintenance of private circuits. It allows end-to-end testing of private circuits from a CTF without the need for manual intervention at any of the exchange sites. Skilled testing staff are therefore more efficiently used and abortive visits are minimised. It allows for the possibility of testing a customer's circuit while the fault is being reported so that rapid diagnosis can be given within minutes of the report. Although initially intended as a means to improve maintenance, RATES also offers benefits during circuit provision.

References

[1] MARSHALL J. F., ADAMSON, J., and COLE, R. V. Introducing Automatic Cross-Connection into the KiloStream Network. *Br. Telecommun. Eng.*, Oct. 1985, **4**, p. 124.

Biographies

John Marshall is a Head of Group in National Networks Trunk Services Engineering Division. He joined BT in 1964 on the scientific grade at BT's Research Station at Dollis Hill and worked for some time on the development of high-reliability transistors for use in deep-sea repeaters. He was awarded a scholarship in 1966 for a full-time B.Sc. Honours degree in Electrical and Electronic Engineering and returned, in 1970, to the Local Line System Development Department where he was involved on early work with wideband television distribution systems. In 1972, he was awarded a scholarship for a one year M.Sc. course in Telecommunications Systems at Essex University and returned to BT's Transmission Systems Development Department, in 1973, where he worked on audio and miscellaneous repeater station equipment development. In 1981, he was promoted to his present position as Head of Group Network Management Systems where he is responsible for a number of major system development projects including RATES.

Roger Gallagher joined BT in 1966 as a Trainee Technician Apprentice and, on completion of his training, joined the maintenance section of the television switching centre at the British Telecom Tower. On promotion to Assistant Executive Engineer in 1975, he joined the audio design development group of the Development Division. Initially, he was involved with the development of new 2- and 4-wire audio repeaters. During this period, he completed a part-time degree course in Electrical and Electronic Engineering. He then became involved in the preparation of functional requirements, system definition and implementation of the RATES field trial project. On promotion to his present grade in 1984, he assumed responsibility for the technical evaluation and support for the national RATES system.

Anil Ratti joined BT in 1975 as a design engineer in the television line systems group. In 1980, he was awarded a scholarship to study for an M.Sc. in Telecommunications Systems at Essex University. On his return to BT, he worked in the Network Management Group dealing with the technical aspects of RATES. He is now head of the Communications Architecture Group in the Public Data Networks Division.

The Development of Single-Mode Fibre Transmission Systems at BTRL

Part 2—Recent Developments

R. C. HOOPER, B.SC., C.ENG., M.I.E.E., and D. W. SMITH, B.TECH.†

UDC 621.391.63

In this, the second of two articles, recent developments in single-mode fibre transmission systems at British Telecommunications Research Laboratories are discussed. The article covers, firstly, improvements in system performance being achieved by enhancement of direct detection systems, and secondly, the further performance improvements becoming feasible by the adoption of coherent transmission technology.

INTRODUCTION

In the first of these articles*, the development of single-mode fibre transmission systems at British Telecom Research Laboratories (BTRL) from 1979 to 1982 was charted. In this second article, some of the developments that have occurred since 1982 are described.

A key development area has been the exploitation of the second low-loss window at 1550 nm allowing yet further increase in repeater spacing. However, it has been found that semiconductor laser sources with confined spectra need to be used in order to obviate the fibre chromatic dispersion of about 15–18 ps/nm/km at this wavelength.

Single-mode fibre cable will be the dominant fibre transmission technology in the UK national trunk network by the early-1990s. Systems technology under investigation in the laboratory is aimed towards the full exploitation of the potential of this medium. The developments are being carried out on two broad fronts.

The first of these is enhancement of direct-detection systems by direct upgrading at 1300 nm bringing information-carrying capacity into the gigabits per second range[1]. The use of the 1550 nm window with narrow linewidth sources is being investigated as a means of further increasing capacity and system range[2, 3]. Capacity may also be upgraded by using passive optical components to permit duplex[4, 5] and wavelength multiplex[6] systems.

The second area of development for future systems enhancement is coherent technology, where the carrier wave properties of semiconductor lasers are utilised to allow more sophisticated modulation and detection schemes to be used. Such systems[7] may exhibit up to 20 dB improvement in sensitivity over direct detection systems, allowing repeater spacings to be increased by possibly more than 100 km. It is becoming clear that this technology does not require fibre different from that being used in current direct detection systems[8].

DIRECT DETECTION SYSTEMS

Single-mode fibre typically exhibits two low-loss windows as shown in Fig. 1. The first appears at 1300 nm and the second at 1550 nm. The second window, however, exhibits chromatic dispersion requiring narrow line sources for operation at very high bit rates(gigabits per second) and long repeater spacings (>30 km).

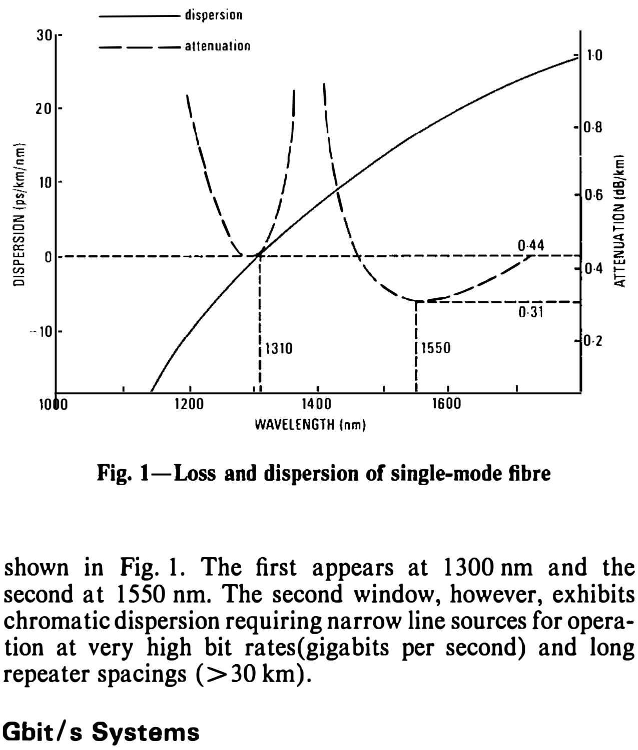

Fig. 1—Loss and dispersion of single-mode fibre

Gbit/s Systems

Systems based at 1300 nm are usually loss limited, that is, the repeater section length is set only by the transmitter coupled power, receiver sensitivity and fibre loss, whereas 1550 nm systems can be dispersion limited, without narrow line sources. However, in practice, it is unlikely that a precise match can be always attained between the laser operating wavelength and the chromatic-dispersion-zero wavelength. For 30 km repeater sections it is unlikely that a serious dispersion penalty will result until information rates of several gigabits per second are reached, although some tightening of the allowable spread of laser centre wavelengths may be necessary. In the case of much longer repeater sections, then the technology of line-narrowed sources developed for 1550 nm could be transferred to 1300 nm.

At BTRL, some experiments have been performed at 1·2 Gbit/s and 1300 nm over a 31 km length of installed single-mode fibre having a chromatic dispersion zero at 1300 nm. An InGaAsP/InP 1275 nm buried crescent laser[9]

† Research Department, British Telecom Development and Procurement

* HOOPER, R. C., PAYNE, D. B., and REEVE, M. H. The Development of Single-Mode Fibre Transmission Systems at BTRL, Part 1—Early Developments, *Br. Telecommun. Eng.*, Jul. 1985, **4**, p. 74.

was modulated with a $2^{15}-1$ pseudo-random binary sequence test signal. The output from the laser was launched into the cabled (MIME†) fibre with a mean launch power of $-5\cdot5$ dBm. At the far end, a PINFET receiver[10] was used for detection. This receiver comprised an InGaAs PIN photodiode having low capacitance and a GaAs MESFET preamplifier having both low capacitance and low noise. The PIN photodiode and GaAs MESFET were mounted on a thick-film circuit hybrid containing silicon bipolar transistors for buffering and amplification. The receiver sensitivity for a 10^{-9} bit error rate was $-33\cdot2$ dBm. The detected electrical signal from the receiver was then regenerated in a regenerator utilising high-speed commercial integrated circuits[11]. The regenerator comprised linear and limiting wideband amplification and a parallel processing decision gate as shown in Fig. 2.

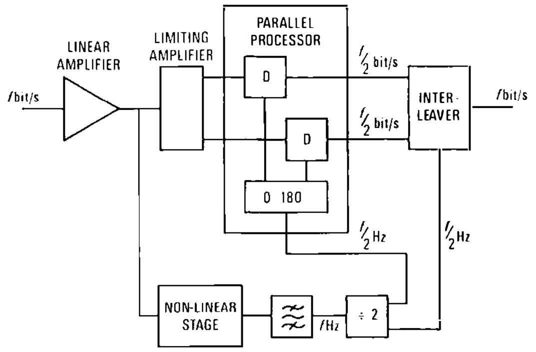

Fig. 2—Parallel processing regenerator

The decision gate comprised two emitter-coupled logic (ECL) D-type bistables operating in parallel at half the bit rate but 180° out of phase. The decisions then took place in each circuit on every other bit. The two streams at 600 Mbit/s were then interleaved to form the 1·2 Gbit/s signal in an integrated transistor array.

A further experiment was undertaken on a length of 54·7 km of reeled single-mode fibre using the same components. The results of the two experiments are given in Table 1, but in neither case was a dispersion penalty measured.

TABLE 1

1·2 Gbit/s 1300 nm Experiments

Link length	31 km	54·7 km
Laser transmitter power	−5·5 dBm	−5·5 dBm
Path loss	15 dB	23·5 dB
Received power	−20·5 dBm	−29 dBm
Receiver sensitivity	−33·2 dBm	−33·2 dBm
System margin	12·7 dB	4·2 dB

Duplex System

Whilst electronic multiplexing techniques have been the favoured method of achieving a direct upgrade of capacity in the past, optical-fibre systems offer a number of possible alternative approaches. Duplex use of the transmission path is possible by using fused tapered single-mode fibre couplers[12]. In these passive devices, generally having four ports, a proportion of the input optical power is transferred to an output port. These devices are reciprocal in that light may travel in either direction through the coupler with equivalent path losses. If two such couplers are inserted in a system at either end of the link, then it is possible to double the capacity of the system by using a single fibre for both directions of transmission simultaneously. If the couplers are arranged to divide the input power equally between the outputs, then an additional loss of 6 dB is incurred. Excess losses less than 0·1 dB have been measured[12]. Experiments were performed in which digital signals were transmitted bidirectionally at bit rates from 34–650 Mbit/s[4]. A schematic diagram of the system used for the experiments is shown in Fig. 3.

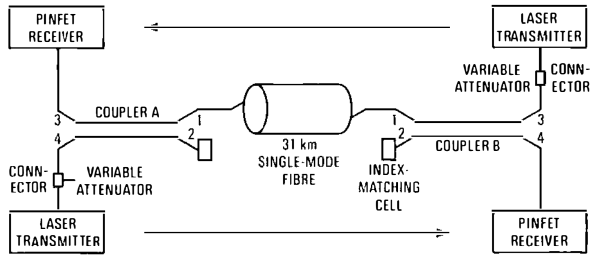

Fig. 3—Duplex transmission at 1300 nm

The two laser transmitters operated at the same nominal wavelength without interaction even when the wavelengths came to within about 1 nm separation. No crosstalk was found and the only additional penalty was due to the backscatter from the fibre which, compared with receiver sensitivity at 34 and 140 Mbit/s, became significant. The high level of system margin obtained even at 650 Mbit/s makes this duplexing method very attractive. The detailed performance of the system is shown in Table 2.

TABLE 2

Duplex System Power Budget

Transmitter power (dBm)		−3·2	(−2·8)	
Total coupler loss (dB)		5·3	(7·6)	
Path loss (dB)		16·2		
Received power (dBm)		−24·7	(−26·6)	
Transmission rate (Mbit/s)	34	140	320	650
Receiver sensitivity (dBm)	−52·5	−46	−43·5	−35·5
Penalty (dB)	1·2	0·3	0	0
Margin (dB)	26·6	21	18·8	10·8
	(24·7)	(19·1)	(16·9)	(8·9)

Note: Duplex power budget A–B (B–A shown in brackets)

1550 nm 1·2 Gbit/s System

Because of the very much lower losses available in the 1550 nm window, it is possible to achieve very much longer repeater separations at gigabits per second speeds. One method of achieving the necessary narrow linewidth of the laser source is to use a *distributed feedback* (DFB) laser[13]. Such a device operating at 1530 nm has been used at BTRL in a 1·2 Gbit/s 114 km experiment[14]. The DFB laser generates a *single longitudinal mode* (SLM) even when

† MIME—Martlesham Ipswich monomode experiment

modulated. The linewidth can be as narrow as a few tens of megahertz under continuous wave (CW) conditions. The DFB laser was modulated from the threshold by a $2^{15}-1$ pseudo-random binary sequence test signal at 1·2 Gbit/s with a peak-to-peak signal amplitude of 36 mA. The power launched into the single-mode fibre tail was −4 dBm. A PINFET receiver having a sensitivity of −35·6 dBm was used at the far end. Fibre links up to 114 km were configured for a series of tests which demonstrated that degradation of performance was incurred as the length increased.

Fig. 4 shows error-rate plots from 10–114 km indicating that penalties of about 3 dB at 114 km have occurred.

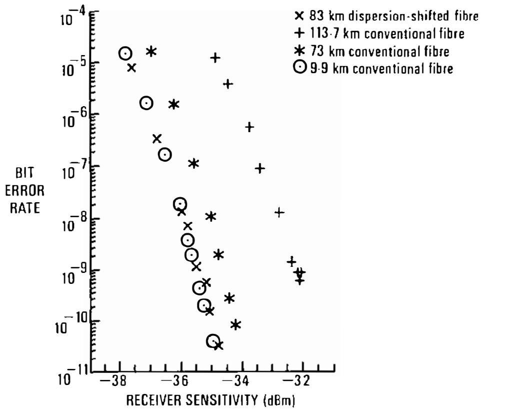

Fig. 4—Error-rate performance

However, by using dispersion-shifted fibre, with the chromatic dispersion zero at about 1560 nm, no such penalties are seen at 83 km. The penalty with conventional fibre must therefore be related to dispersion. Although the DFB laser is SLM, the mode shifts during the transient turn-on by about 0·24 nm. This shift appears as intersymbol interference which becomes measurable after about 50 km. It is possible to reduce the effect of this *chirp* by slowing the response of the device, in particular the relaxation oscillation or, alternatively, by using electrical compensation in the drive current waveform[15]. One method of overcoming chirp completely is to operate the device CW into an external modulator. However, such devices will have some loss associated with them which could be higher than the chirp penalty. Nevertheless, with higher output powers from laser sources, the external modulator is an attractive proposition.

Type T Fibre

The loss of conventional step-index 1300 nm based single-mode fibre can reach just under 0·2 dB/km at 1550 nm. It is possible to shift the dispersion zero to 1550 nm with the conventional design, but because a smaller core diameter and a higher refractive index difference are required, the loss at 1550 nm can be 0·35 dB/km or greater. The higher loss is associated with stress at the core/cladding interface, but this can be minimised by grading the refractive-index profile of the core. The triangular profile or *Type T* fibre[16] allows the zero-dispersion wavelength to be shifted from 1300 nm to 1550 nm without substantial change in loss at 1550 nm.

Some initial experimental studies using uncabled Type T fibre fabricated at BTRL were undertaken in late-1983. Transmission of 140 and 320 Mbit/s signals over 103·6 km of Type T single-mode fibre was achieved by using a BTRL 1550 nm laser chip. The link length was subsequently reduced to 83·3 km and a 650 Mbit/s signal successfully transmitted. The power budgets for these experiments are given in Table 3. The penalty of 0·5 dB for the 650 Mbit/s experiment arises from the mismatch of the laser centre wavelength and the fibre dispersion zero. However, these experiments have exhibited essentially loss-limited performance.

TABLE 3

Type T Fibre System

Bit rate (Mbit/s)	140	320	650
Link length (km)	103·6	103·6	83·3
Launch power (dBm)	−7·8	−7·8	−7·8
Loss (dB)	34·2	34·2	26·2
Received power (dBm)	−42	−42	−34
Receiver sensitivity (dBm)	−46·8	−42·2	−35·5
Margin (dB)	4·8	0·3	1·5
Penalty (dB)	0	0	0·5

COHERENT SYSTEMS

The maximum distance between repeaters in an optical-fibre transmission system could be further increased if coherent transmission instead of direct detection is used. With *coherent detection*, the weak input signal is combined with a strong local oscillator signal prior to photodetection. Because of the square law nature of photodetection, this mixing process results in conversion gain which effectively amplifies the detected signal photocurrent above the noise of the following electronic preamplifier. Since present-day direct-detection receivers are not quantum-noise limited, it is possible to achieve considerable improvements in receiver sensitivity, possibly by as much as 20 dB[7], by the use of coherent detection.

This theoretical benefit of coherent optical detection over direct detection has been widely appreciated since the invention of the laser and, in fact, some early line-of-site optical transmission experiments used heterodyne detection. Then, as interest developed in optical-fibre transmission using multimode fibre and broad linewidth semiconductor lasers, coherent techniques had to be temporarily abandoned. More recently, with the almost universal move to single-mode fibre for long-distance fibre transmission, the emergence of integrated optic technologies, and the tremendous progress in improving semiconductor laser spectral purity, laboratory demonstrations of coherent optical-fibre transmission are now possible. This second phase of research was initiated in laboratories in Europe and Japan, and is now carried out in all major telecommunication laboratories throughout the world.

Polarisation Stability

Polarisation stability of the transmission media was an initial worry because coherent detection is polarisation sensitive. Conventional circular symmetric single-mode fibre does not preserve the initial launched polarisation state throughout the transmission path. This is because any residual strain-induced birefringence left within the fibre after cable installation will be subject to environmental fluctuations and result in an output polarisation state which is in practice unpredictable. Although polarisation-holding fibres have been proposed and demonstrated[17], they currently have higher loss and are usually more complex than conventional fibres. Moreover, since much of the long-distance transmission network is already using or is planning to use standard single-mode fibre, there are great benefits if coherent detection schemes are fibre compatible with direct detection. Fortuitously, it has been found that although the polarisation state from standard fibre cannot be predicted in advance, its output state remains stable for long time periods, several hours for cabled fibre installed in ducts under the ground[8].

This slow polarisation fluctuation can be dealt with in the coherent receiver by using a polarisation control system that adjusts either the local oscillator polarisation or input signal polarisation. There are several techniques that can be used, including electromechanical, magneto-optic and electro-optic devices; the latter can be elegantly realised in integrated optic form[18]. However, for laboratory experiments, manual control has been sufficient.

Components for Coherent Transmission Systems

For coherent transmission, the sources used in the transmitter and for the receiver local oscillator must have spectral linewidths considerably narrower than those usually encountered in direct detection systems. The linewidth required depends upon the type of modulation and demodulation used. Homodyne detection with phase-shift keying (PSK) modulation offers the highest performance, but is most demanding on source spectral characteristics; for instance at 140 Mbit/s, linewidths of less than 100 kHz, or about 10^{-6} nm, are required. For these schemes, it has been necessary to reduce dramatically the spectral linewidth of semiconductor lasers. Two techniques that have been particularly successful to achieve this are injection locking, and the use of selective external cavities. The former is achieved in practice by coupling the output from a stable 1520 nm wavelength HeNe gas laser into a semiconductor laser[19]. However, the external cavity laser approach (see Fig. 5) offers a more versatile solid-state alternative which, as well as having a linewidth of only a few kilohertz, can be tuned over a wide frequency range; a tuning range of about 10 000 GHz has been achieved for sources implemented by anti-reflection coated laser chips and diffraction-grating loaded external cavities of between 50 and 200 mm length[20]. Alternatively, for the less demanding applications requiring linewidths of a few tens of megahertz and limited tuning, the use of DFB lasers without external cavities has the attraction of small size, but is, however, extremely critical on the need for non-reciprocal optical isolation.

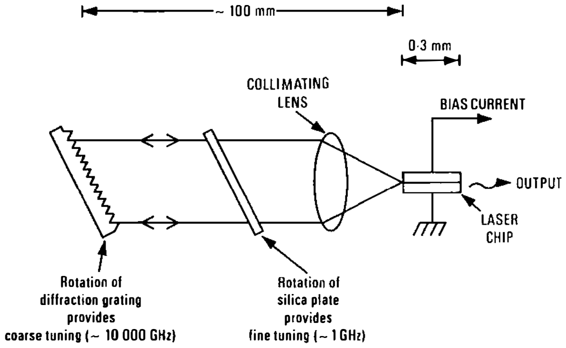

Fig. 5—External-cavity semiconductor laser

Coherent transmission requires a wide range of micro-optic, fibre optic and integrated optic devices. These include planar waveguide lithium niobate phase modulators for PSK systems, polarisation controllers, fibre directional couplers for signal combination and optical isolators. The optimum design of these transmission systems requires optical circuit design skills analogous to those of the traditional electrical circuit designer. Fig. 6 shows an example of an experimental PSK heterodyne transmission system indicating the range of optical, electro-optical and electronic components necessary.

First Demonstration of Improved Sensitivity

The first demonstration of an improvement in receiver sensitivity over a good direct-detection optical receiver by coherent detection was in an amplitude-shift keying (ASK) homodyne experiment at BTRL in 1982[21]. This rudimentary experiment used injection locking to line narrow a buried crescent semiconductor laser that was directly modulated. A single 1520 nm HeNe laser was used both as the input signal to the diode laser and as the local-oscillator laser. To overcome problems of wavefront matching, fibre-based components were used both for polarisation control and beam combination. To avoid the need for large local-oscillator powers and still achieve close to shot-noise-limited detection, a low-noise PINFET receiver was used in the experiment. This experiment with self homodyne detection and with ASK modulation was also repeated with PSK modulation; a combination that should give the ultimate in receiver sensitivity for a binary transmission system. The best ever sensitivity measurement achieved with a pseudo-random bit sequence[22] was −62 dB at 140Mbit/s, just 4 dB away from the quantum limit and 17 dB better than that which could be achieved with the same receiver in a direct-detection mode.

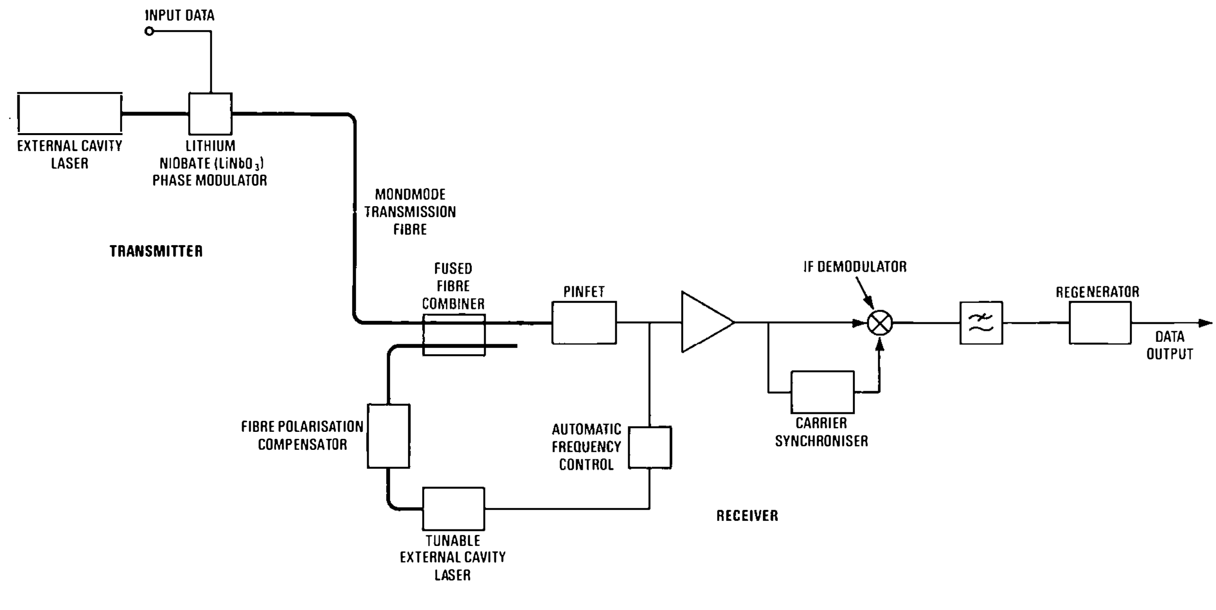

Fig. 6—Optical PSK transmission experiment

TABLE 4
Improved Sensitivity Receiver

Modulation	Transmitter	Receiver	Fibre Path	Sensitivity
ASK	HeNe	Self homodyne	1 m	−59 dBm
ASK	External cavity	Heterodyne external cavity	60 km	−53 dBm
FSK	External cavity	Heterodyne external cavity	200 km	−56 dBm
FSK	DFB	Heterodyne external cavity	1 m	−50 dBm
PSK	HeNe/$LiNbO_3$ modulator	Self homodyne	1 m	−63 dBm
PSK	HeNe/$LiNbO_3$ modulator	Optical PLL homodyne	30 km	−57 dBm
PSK	HeNe/$LiNbO_3$ modulator	Heterodyne external cavity	109 km	−59 dBm
DPSK	HeNe/$LiNbO_3$ modulator	Heterodyne external cavity	109 km	−57 dBm

System Results

Experiments have now been performed at BTRL on a range of coherent transmission configurations featuring either homodyne or heterodyne detection with either amplitude, phase or frequency modulation. In addition, both DFB and external-cavity laser sources have been considered, and transmission over fibre path lengths up to 200 km[23] achieved. Table 4 summarises results at 140Mbit/s data rate.

As expected, the best results in terms of receiver sensitivity have been achieved by using PSK modulation and homodyne detection over a short fibre path. Matching this performance over longer transmission paths will depend critically on the development of high-performance optical phase-lock loops[24]. Homodyne detection has one other significant advantage over heterodyne detection in that it is much more efficient in its use of the available receiver bandwidth, a factor of increasing importance as coherent transmission principles are applied to gigabits per second systems. Very recently, a homodyne receiver with bandwidth in excess of 1·5 GHz and featuring a local oscillator comprising a phased-locked semiconductor laser has been demonstrated[25], indicating that coherent transmission of several gigabits per second is now a realistic possibility in the laboratory. At the opposite extreme of complexity, experiments with DFB lasers[26] and large-deviation FSK that feature single-filter detection, although less demanding in terms of source characteristics, have been unable to produce, as yet, significant improvements over direct detection. As far as total system budget is concerned, the option of using narrow-deviation FSK has much to commend it, since direct frequency modulation by injection current eliminates losses in an external phase modulator. Performance approaching PSK could, in principle, be achieved by an optimised form of narrow-deviation FSK such as *minimum-shift keying*.

WIDEBAND NETWORKS

In addition to increasing unrepeatered transmission distance for intercity communication systems, coherent transmission could greatly increase the versatility of future optical wideband distribution networks and local area networks (see Fig. 7). For this application, the improvement in receiver sensitivity could be used to increase distribution losses and the selectivity of a tunable coherent receiver to isolate a single channel from an optical frequency multiplex. The basic principle of this has been demonstrated in a recent two-channel experiment where it was possible to select at

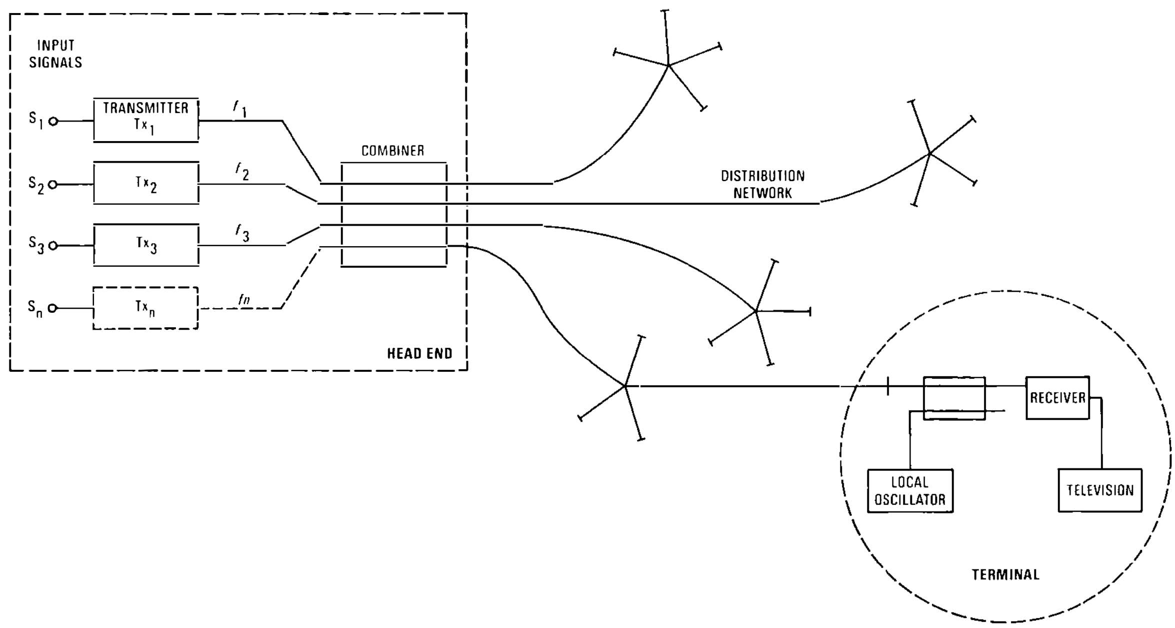

Fig. 7—Hypothetical future coherent wideband distribution system

the receiver between two PFM video channels spaced at optical frequencies just 1 GHz apart[27] (there is about 50 000 GHz bandwidth available between 1200 nm and 1600 nm).

The ultimate transmission capacity of a network built around coherent transmission principles is still a matter of speculation. Although, in fact, the future initial deployment of coherent transmission systems in the field, possibly in the early 1990s, will depend more on advances in the engineering of narrow linewidth lasers, improvements in the performance of DFB/DBR lasers and the commercial development of integrated optic components rather than on any fundamental physical constraints.

CONCLUSION

In the British Telecom national network, single-mode fibre is becoming a standard technology for cable transmission. It is now clear that this technology has enormous potential information carrying capacity. Upgrading systems from 140 Mbit/s to 1·2 Gbit/s at the same repeater spacing is viable at 1300 nm and 1550 nm ,with the latter wavelength giving some scope for increase in repeater spacing provided line-narrowed sources are employed. Alternative upgrading options exploiting duplex operation involving only passive optical components are feasible. An alternative low-loss fibre with dispersion zero at 1550 nm is emerging as a realistic long-term competitor to conventional step-index single-mode fibre. The single-mode fibre installed or being installed in the network now appears compatible with coherent systems allowing yet further upgrading potential. Whether the higher performance coherent systems will have more impact on traditional point-to-point links or on distribution and networking applications is a matter for speculation.

Acknowledgement

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Biographies

Raymond Hooper joined the Post office as a Trainee Technical Apprentice in London North Area. After graduating with an honours degree in Electrical Engineering from Middlesex Polytechnic in 1970, he joined the optical-fibre communications project at the Research Department. He has been involved in all the major BTRL field demonstrations of optical-fibre transmission systems and was responsible for the field systems measurements with the installed single-mode fibre cables. He now heads a group working on advanced direct detection systems and receivers operating at gigabits per second information rates.

David Smith joined British Telecom in 1967 as an apprentice. In 1974, after graduating from Brunel University, he returned to the Martlesham Research Laboratories to work in the area of electronic switching. In 1977, he joined the optical communications division to become involved in the application of semiconductor lasers to optical transmission systems. Since 1981, he has been head of a group investigating coherent optical transmission.

The Analysis of System X Processor Performance Under Transient Traffic Conditions

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This article, which is an abstract of a paper presented to the 11th International Teletraffic Congress, Kyoto, Japan, in September 1985, reports on a study of the performance of the processor in a System X digital main switching unit in the new digital trunk network under transient traffic conditions. It outlines the computer simulation model used, and discusses the results obtained.*

INTRODUCTION

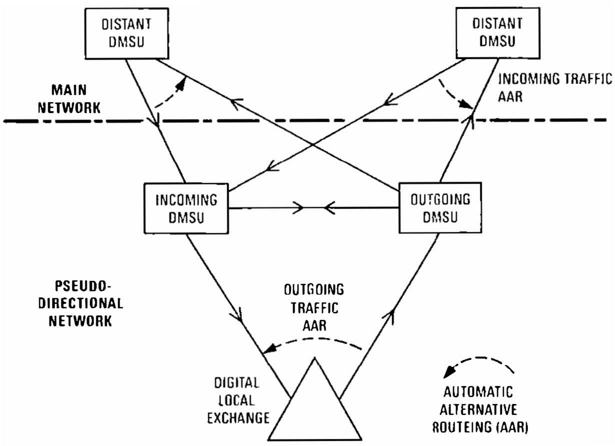
The plan for an integrated digital network now being implemented by British Telecom (BT) envisages a completely new trunk network structure. This new network, and the System X switching units to be employed in it, have been extensively studied by BT's Teletraffic Division under a range of traffic conditions including normal loads, steady-state overloads, transient overloads and partial failure conditions. A study of System X processor performance under a transient traffic loading that could occur in the new network has been conducted using a computer simulation model of the processor. The processor itself, the load control scheme employed, and the simulation model are all discussed along with results obtained from the simulation of the transient overload.

PSEUDO-DIRECTIONAL NETWORK

In the new trunk network structure, some 400 existing analogue trunk switching units are being replaced by about 60 System X digital main switching units (DMSUs). Most DMSUs will be singly located and fully interconnected, and will switch traffic in both directions. In some large cities, however, the volume of trunk traffic to be switched will warrant two or more DMSUs.

A particular case arises when two DMSUs are located in a large city and are required to be mutually supportive in the event of a system failure. To meet this need, a 'pseudo-directional' dual-unit network has been designed, as shown in Fig. 1. Normally, one of the DMSUs carries all the traffic incoming to the city and the other all traffic outgoing from the city. If a route to one DMSU becomes congested, then new calls encountering congestion will automatically overflow to a nominated route to the other DMSU, by using the facility offered by System X of *automatic alternative routeing* (AAR). This requires the second DMSU to switch the overflow traffic in the opposite direction to its normal traffic flow.

Therefore, in the event of one DMSU failing, all calls proper to that unit would be offered to the other, which would thus become a fully bothway unit. This extreme situation has been judged to represent the worst possible case of DMSU overload that could be encountered in the trunk network. It was therefore selected for a teletraffic investigation of DMSU processor performance under extreme transient overload.



DMSU: Digital main switching unit

Fig. 1—Pseudo-directional network

TRANSIENT CALL ATTEMPT PROFILE

The transient call attempt profile offered to a system under system failure conditions clearly depends on a very wide range of factors including network configuration, repeat attempts and network management. It was not necessary to consider all these factors in detail for the study since its main purpose was to verify the satisfactory operation of processor load control (PLC) under the severe transient call attempt overload conditions that could arise in the network. Thus a 'worst case' transient was constructed, after consulting CEPT's† requirements for transit exchanges[1].

Many of the parameters defining the transient profile, including:

traffic type,
peak calling rate, and
transient duration,

were arbitrarily selected to give the worst possible representation of the transient profile likely to be offered to the processor. The transient call attempt profile for which results

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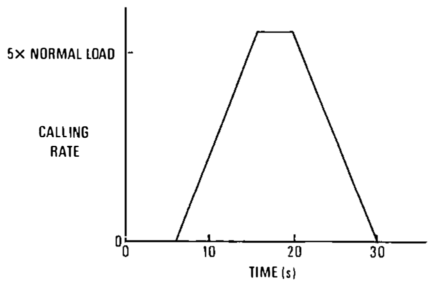
* BONSER, J. The Analysis of Transient Performance for Nodal Failure in an Alternative Routeing Network. 11th International Teletraffic Congress, Kyoto, Japan, 1985.

† Conference of European Postal and Telecommunication Administrations



Note: The total call attempt profile is obtained by adding a steady-state loading to this transient

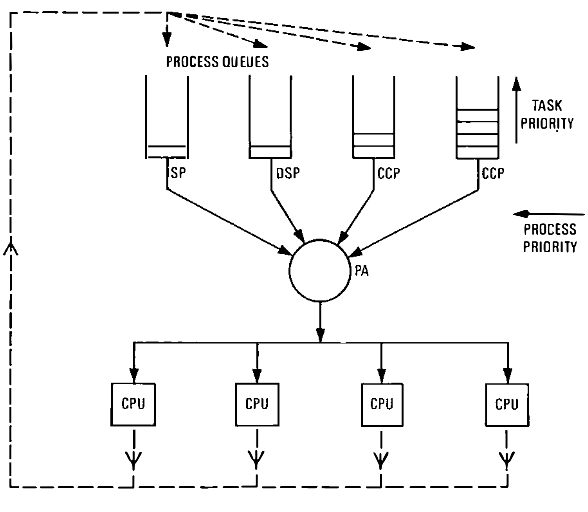
Fig. 2—Transient call attempt profile

are given in this article is shown in Fig. 2. At its peak, this transient profile has a call attempt rate approximately 5 × normal load. This profile was added to steady-state traffic levels of normal load and 50% overload to obtain a total call attempt profile. This total call attempt profile, of course, represents a gross overload of the DMSU processor. The initial steep rise in call attempts results from the rapid transfer of new attempts from the failed DMSU plus attempts to re-establish calls that were in progress when the failure occurred. In practice, not all of these attempts would reach the working DMSU over such a short period because of the limitations imposed by route capacity, but this does not matter since the objective is to represent the worst possible situation in terms of both rate-of-increase and peak value. Similarly, the decay of call attempts would in practice be more prolonged and intermittently peaky. Variations of this profile were therefore investigated to take these factors into account to allow the effect of variation in the parameters to be determined.

DMSU PROCESSOR

The control processor which is used in a System X DMSU, and the teletraffic simulation model of the processor have already been described in detail[2, 3]. The processor is outlined in Fig. 3. This shows that it consists of up to four central processing units (CPUs) and their associated hardware, collectively termed a *cluster*. Clusters can be interconnected to provide additional processor power if required.

The software on the processor is organised into *application*



CCP: Call control process
DSP: Digital switching process
PA: Process allocator
SP: Signalling process

Fig. 3—DMSU processor

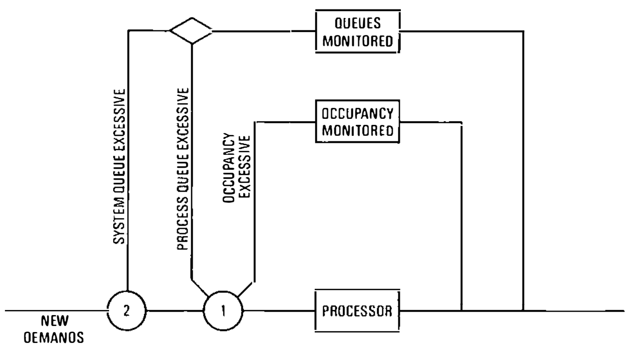
programs (APs) performing such functions as signalling, switching, and call control. These APs are served in priority order. Each AP has its own *process queue* and the aggregate of all process queues is termed the *system queue*. The scheduling of the APs and the communication between them is controlled by the *process allocator* (PA).

Thus the processor is a multiserver priority queueing system, and it has been simulated as such when the system performance under transient traffic conditions has been determined.

PROCESSOR LOAD CONTROL

The purpose of processor load control (PLC) is to regulate the work performed by the multiprocessor so that, under call attempt overload or failure conditions, the number of tasks within the process queues does not build up to an excessive level. Should the total number of tasks exceed the maximum allowed in the system queue, the consequences would be dire, because the multiprocessor would cease handling any work at all and would need to be restarted.

The multiprocessor uses a dual scheme to perform load control as shown in Fig. 4. First, workload limits are used



1 New call rejected and routed to tone.
2 All inputs inhibited.

Fig. 4—Processor load control

to control the acceptance or rejection of new calls (represented by sequences of the APs) so that the maximum number of calls in the set-up phase at any instant does not exceed a given workload limit. A monitoring period of approximately 5 s is specified (the periodicity is adjustable) and, in each period, information is gathered on the CPU occupancies, the calls accepted, the calls rejected and the maximum number of calls in the set-up phase. Based on this information, new workload limits are calculated for the next monitoring period to ensure that the average CPU occupancy does not exceed a specified value, say 0·9.

The second part of the scheme involves thresholds on the process queues and the system queue. If the number of tasks within a process queue or the system queue exceeds a preset, upper, threshold, an overload is indicated. The end of the overload occurs when the number of tasks is reduced below another preset, lower, threshold. There exists a degree of flexibility as to the action invoked when an overload is in progress, but, generally, a process-queue overload causes all new calls to be rejected for its duration, and a system-queue overload causes the input of all tasks from the peripheral units to be inhibited.

The mode of operation of the dual-load control scheme is such that, during call attempt overload, regulation of the CPU occupancy enables the acceptance or rejection of new calls to be controlled in a stable and smooth manner. In more severe circumstances, such as a large transient overload, the thresholds provide direct protection against an excessive number of tasks in a process queue or the system queue.

PROCESSOR SIMULATION MODEL

The performance of the processor has been observed by using a simulation model. The model has been designed to simulate the interaction between PA, PLC and the APs for a single cluster, with the added facility of being able to represent intercluster communication for a multicluster configuration. It has been progressively developed over a period of years from the early processor design concepts to the current multiprocessor multicluster configuration. This development of the model has been facilitated because, firstly, the process structure of the software has been carried forward almost unchanged through the major design changes of the multiprocessor hardware and, secondly, the decision was taken at an early stage that most of the multiprocessor design details would be defined through input data to the model. New multiprocessor designs have therefore been relatively easy to model by changing this data.

The model has been programmed in PL/1 and uses the Telesim event-by-event simulation package, which has been specifically developed by BT's Teletraffic Division for teletraffic performance analysis. The Telesim package, which runs on an IBM 3084 computer, undertakes the scheduling of events and provides for the handling of histograms and confidence-interval routines. The model thus consists of a set of event-by-event action blocks, and Telesim schedules the action blocks to run in the order in which they occur in real time.

The model provides the following main facilities:

(*a*) a variable number of CPUs;
(*b*) a variable number of APs;
(*c*) a variable number of process sequences, representing call progression through the APs;
(*d*) timing values for AP run times and PA run times; and
(*e*) results giving details of:

(*i*) CPU occupancies;
(*ii*) AP occupancies;
(*iii*) AP queueing delays;
(*iv*) AP queue lengths;
(*v*) processor grade of service;
(*vi*) behaviour of PLC parameters; and
(*vii*) history of the above during a simulation run.

The model can generate several call arrival patterns including random (Poissonian) arrivals. The mean inter-arrival time of these random arrivals can itself be a function of time, and this facility enables the model to be used to simulate transient traffic conditions.

RESULTS

The processor performance observed by using the simulation model is shown in Figs. 5, 6 and 7. Each figure includes two curves corresponding to the observed performances of processors during the application of the transient call attempt profile from an initial steady-state load of

normal load (full line), and
50% call attempt overload (broken line).

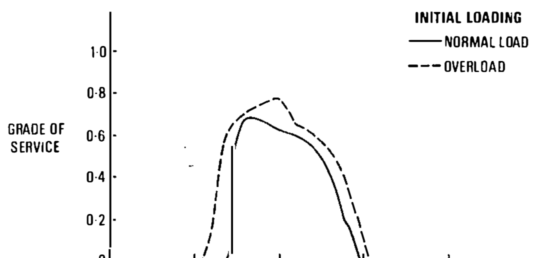


Fig. 5—Processor grade of service

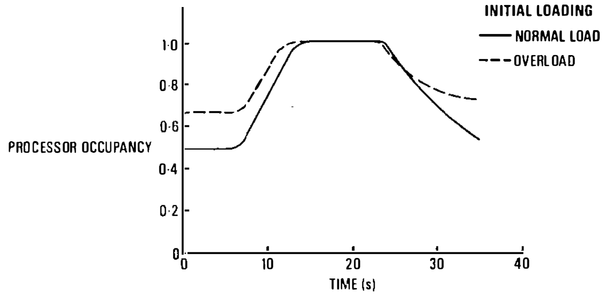


Fig. 6—Processor occupancy

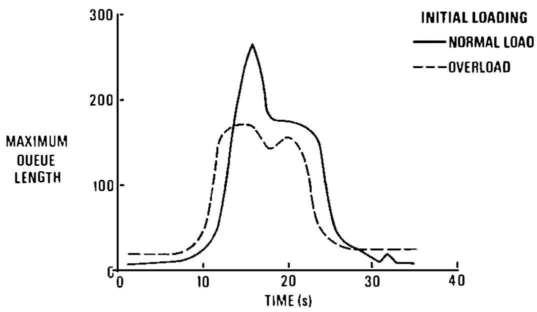


Fig. 7—Processor queue length

Fig. 5 shows that the processor continues to process some calls successfully during the transient period, albeit at a poor grade of service, and recovers rapidly when the transient is removed.

The processor occupancy observed under these transient conditions is illustrated in Fig. 6. This shows that the occupancy rapidly rises to almost 1·0. At this occupancy, the processor is accepting as many calls as possible and rejecting the remainder.

Fig. 7 demonstrates two interesting features about the processor queue lengths observed:

(*a*) System-queue length rises higher when the processor is initially carrying a normal load than when it is initially overloaded. This reflects the fact that the PLC parameters are set to accept a smaller increase in call attempt rate at overload than at normal load.

(*b*) System-queue length remains below its threshold, set for the purpose of this study at 300, and well below its limit, throughout the transient. This means that (see Fig. 4) all new calls are either carried or rejected, and no new demands from the signalling systems are inhibited. Hence, all calls that have been accepted and are being set up continue to completion, and all cleardowns are successfully processed.

Thus the results show that under severe transient overloads the processor will continue to accept some call attempts. The remainder will be rejected and routed to tone in a controlled manner, with normal operation quickly being restored once the transient overload condition is removed.

Further results showed the effect of varying the somewhat arbitrarily chosen transient parameters:

Traffic Type The major effect of the traffic type is to determine the loading offered to the processor.

Peak Calling Rate The peak calling rate primarily determines processor occupancy and, if that becomes excessive, determines the grade of service occurring during the transient.

Transient Duration The results show that the processor recovers rapidly from transient overloads, and thus the transient duration has little effect on processor performance other than determining the time at which the processor returns to normal.

CONCLUSION

This article has described how a computer simulation model of the System X processor has been used to verify the satisfactory operation of processor load control under conditions of extreme transient traffic overload. The results demonstrate that the processor will continue to accept some new calls and successfully complete those in set-up or progress under these conditions, and that normal operation is quickly restored once the transient condition has been removed.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues, including particularly Dr. R. H. Thompson, Mr. K. J. Miller and Mr. J. L. C. Grimbly, for their contributions to the studies which this article describes.

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Biography

John Bonser joined BT in 1971, having obtained an honours degree in Electrical Engineering from Southampton University. He joined the Performance Engineering Division in 1972 and has studied the traffic characteristics of TXE4 and System X exchanges. He is currently a Head of Group in the Performance Engineering Division and is investigating system development and processor modelling.

British Telecom Press Notices

Maritime Telex Modernisation

Telex messages for shipping on the high seas can now be received, stored and relayed later all automatically through a new computer-based system installed at British Telecom's (BT's) Portishead longe-range radio station in Somerset. Previously, storage and later transmission of Telex messages was done manually by operators. Now, once a vessel is ready to receive the Telex message, the new system automatically transmits. The new equipment, which came into service in November last year, marks a significant stage in the modernisation of BT International's (BTI's) maritime radio communications services.

To receive messages automatically during predetermined times, ships enter their own watchkeeping arrangements to the database of the Portishead computer. A land-based customer wanting to send a Telex to a ship sends the message on a Telex machine in the normal way. The message is relayed to Portishead, where it is held on the radio station's computer, and forwarded to the ship. In this way, Telex messages can be received on board ship within minutes, almost anywhere in the world. Ships not supplying watchkeeping instructions are called regularly by Portishead until the messages have been successfully delivered.

Users of the service can also send multiple messages during a single call. This feature will benefit companies using modern Telex terminals with memory and prerecorded address-list facilities. One exclusive feature of BTI's radio Telex service is the frequency watch facility; this enables watchkeeping instructions to be sent automatically to Portishead. Up to 10 instructions a day can be stored, for a maximum of 21 days.

Message Link

British Telecom Radiopaging has introduced the latest addition to its range of services—a new communications system called *Message Link*.

Message Link offers customers an advanced telephone message-taking service that is linked to a British Telecom (BT) Radiopager. Users of Message Link are automatically paged whenever a message is left in their personal voice 'mailbox'. The new system enables companies to ensure that all telephone callers can leave messages and receive responses to them quickly, even when nobody is available to answer the telephone. Companies can immediately provide a 24-hour answering service to customers simply by printing the Message Link number on company stationery or by advertising it in Yellow Pages.

Subscribers to Message Link receive:

(*a*) any pager of their choice from the BT Radiopaging range, and this is given a special Message Link tone alert;

(*b*) a private voice mailbox on a fully-computerised message-taking service, which will automatically trigger the tone alert on their pager whenever a message is left on the system; and

(*c*) a multifrequency keypad that enables the user to access and retrieve messages from their voice mailbox from virtually any telephone in the country.

The electronic mailbox acts as a fully-computerised message-taking service with a personalised greeting, which can be changed or modified at any time by the customer using the Message Link keypad. The mailbox can store up to 10 messages, each of which can be up to 25 s long. An indication is given to the caller if the mailbox is full. Messages are kept on the computer for 24 hours, after which they are automatically deleted. When a message is left on the mailbox, the computer automatically sends out a paging alert, and two reminder alerts are sent out at half-hourly intervals after the original call. The Message Link customer then calls his or her private Message Link number to retrieve the message, and instructs the electronic mailbox to repeat, delete or save the message.

Message Link is a flexible alternative to the telephone answering machine for the self-employed and small companies. It can act as a fully automated receptionist/message-taking facility with the added bonus of a forwarding alert.

As well as offering the automated receptionist/message-taking role in large companies, it can be used by managers to contact staff in the field without the time-consuming effort needed to locate them. The system can also be used to 'broadcast' information to groups of people such as salesmen or service engineers.

Subscriber Line Interfaces

J. R. W. AMES, B.SC., M.SC.

UDC 621.395.126.2 : 621.395.722

Analogue line units contribute up to 60% of the cost of a digital local exchange. Modern designs of these units make extensive use of thick-film technology in the subscriber line interface circuit (SLIC) and codec area in order to produce cost-effective realisations. This article discusses how the development of a fully integrated SLIC presents a significant challenge to analogue technology. It goes on to show that the most significant savings in space will be produced by the replacement of relays and protection components with miniature electronic devices, thus giving the opportunity to consider changes in the design of equipment practice hardware and of the exchange system itself.

INTRODUCTION

Interface circuits between a digital exchange and the outside world represent a considerable proportion of the total cost of that exchange. Details vary from system to system and depend on the size and traffic of the exchange, but it is generally agreed that interfaces account for at least 60% of the cost of a typical installation. In recent years therefore, much attention has been focussed on the design of the analogue line units and their associated subscriber line interface circuits (SLICs) and codecs. The design of such components has represented a significant challenge to integrated circuit technologies and it is only now that cost-effective solutions that also meet public network performance requirements are emerging. Thick-film hybrid circuits have, however, offered a useful stepping stone to full integration. This article describes two typical state-of-the-art realisations before discussing the future of the analogue line unit and its components.

FUNCTIONS OF AN ANALOGUE LINE UNIT

An analogue line unit terminates the subscriber's line, providing power feeding and supervision of signalling conditions. In addition, it converts between the analogue signals present on the 2-wire subscriber's line and the digital code on the 4-wire circuit that is switched by the exchange. It is this unit that determines the transmission characteristics of an integrated digital network; its design must therefore represent a compromise between good transmission performance and cost-effective realisation.

The acronym *BORSCHT* summarises the functions of a line unit:

B: Battery feed
O: Overload protection
R: Ringing generation or application
S: Supervision and signalling
C: Codec
H: Hybrid (2/4-wire conversion and loss adjustment)
T: Test access

Fig. 1 shows a block diagram of a typical analogue line unit. It illustrates that the BORSCHT functions can be divided into two areas: the SLIC and the codec; it also shows control logic which converts signalling conditions into a form suitable for the exchange control processor. Whilst the SLIC and codec elements normally contribute the major part of the cost of a line unit, the control element should not be neglected, especially as the price of other components falls.

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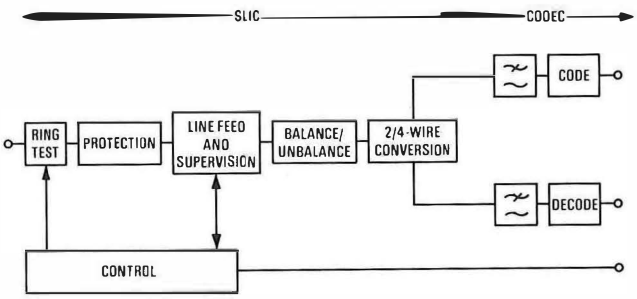


Fig. 1—Line unit

THICK-FILM HYBRID LINE UNIT

An eight-port line unit, developed by British Telecom Research Laboratories (BTRL), is illustrated in Fig. 2. A single printed-wiring board measuring 345 mm × 286 mm houses the eight lines. The individual components are no more than 11 mm high.

An all-electronic SLIC is used which needs no wound components and which feeds a constant current of 40 mA to the subscriber's line whilst maintaining a high degree of impedance balance about earth. In order to meet public network standards of performance, the circuit provides separate complex input and 2/4-wire balance impedance, together with automatic regulation of the loss in the transmit and receive directions[1]. This SLIC uses commercially-available operational amplifiers and transistors which are purchased mounted in small-outline style surface-mounting packages. These packages, together with surface-mounting capacitors and printed resistors, are mounted on thick-film hybrid substrates, three of which make up the complete SLIC.

The codec and filter devices are mounted in low-cost glass-

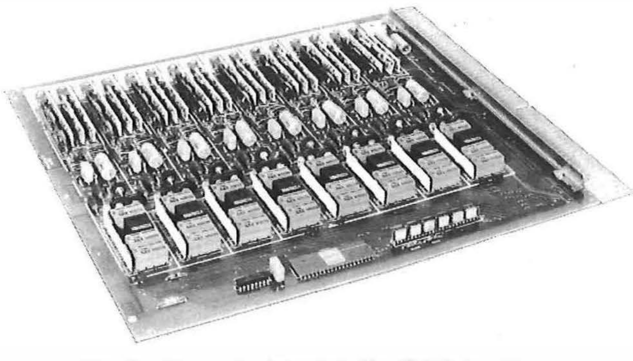


Fig. 2—Line unit with thick-film SLIC circuits

fibre chip carriers[2] which, together with other surface-mounting components, are assembled onto a substrate of glass-fibre printed-wiring board material.

This line unit is compact and cost effective whilst providing an analogue interface to the full public network standard required by British Telecom.(BT). There are, however, areas in which improvements can be made as technology continues to advance. Circuit complexity can be reduced and transmission performance improved as integrated SLIC devices become available and as the increasing processing power that is becoming available in the codec area is exploited. It is clear from Fig. 2, however, that less than half of the board area devoted to each line circuit is occupied by the signal processing circuits (SLIC and codec) and that development of replacements for the remaining bulky components would increase the efficiency of use of space.

FUTURE DEVELOPMENT

Subscriber Line Interface Circuit

The SLIC described above demonstrates clearly that surface-mounting technology can be used to produce a high-quality and cost-effective product in advance of a fully integrated realisation. Much effort is, however, now being directed at the problem of producing an integrated SLIC, and products offering varying levels of performance and integration have now been announced by a number of semiconductor manufacturers. Integrated products have taken some time to appear on the market and there is still some way to go before an ideal component is produced. This apparent delay is hardly surprising when some of the technical problems concerned with the design are considered:

(*a*) *High voltages* 1·5 kV lightning, 250 V RMS public electricity supply, 100 V ringing, 50 V battery.

(*b*) *Potential for high power dissipation* Up to 2 W with 40 mA constant current feed, over 5 W with constant voltage feed.

(*c*) *Large interfering signals* 20 mA or more of induced 50 Hz signal, several volts of induced radio-frequency signals.

(*d*) *Large dynamic range* Audio signals as small as −90 dBm (approximately 50 μV) call for an audio dynamic range of at least 90 dB; up to 120 dB may be necessary in output stages if ringing is applied by the SLIC itself.

(*e*) *Precise transmission specifications* For example, frequency response of ±0·1 dB calls for wide-bandwidth feedback amplifiers.

This combination of problems makes it very difficult to realise the whole SLIC function in a single chip. Indeed, it may not be possible to integrate fully the SLIC function whilst meeting all network requirements. A number of partially-integrated SLIC devices have become available recently and BTRL has been evaluating them in close collaboration with their manufacturers. One of these devices, which uses a 70 V bipolar technology, has been used as the basis of a new line interface unit for the UXD5 digital exchange[3]. This unit, which houses eight analogue interface circuits, is illustrated in Fig. 3. The limits of integration are such, however, that much of the transmission circuitry is external to the SLIC and it is still necessary to use surface-mounted discrete components in this area. Overall, the SLIC has been reduced in area by some 20% and the remaining functions have not been significantly affected by the increased integration. The advantages that this integration brings are the reduction in the cost of the components and assembly, and in the simplification of test procedures during manufacture.

In the future, it is likely that only the output stages will be integrated onto a separate higher voltage device, the remainder of the audio signal processing (including coding) being carried out by one additional device which uses either analogue or digital techniques[4].

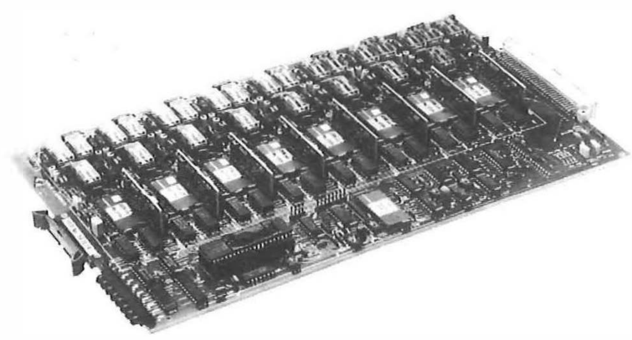


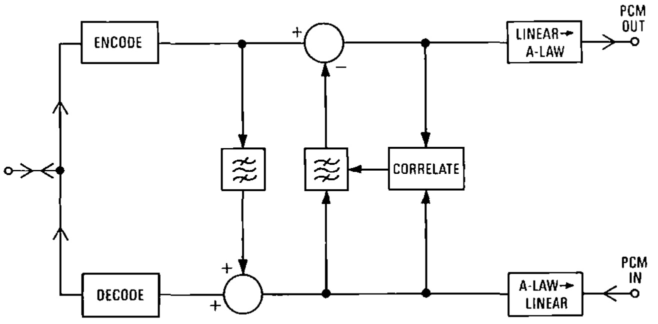
Fig. 3—Line unit with integrated SLIC device

Codec and Signal Processing

Cheap single-chip codec/filter (cofidec) devices are now available both in 16-pin dual-in-line and in surface-mounting packages. The majority of these circuits use linear time-quantised switched capacitor techniques and provide very good performance, particularly because the problem of compatibility between separate codec and filter devices from different manufacturers no longer exists. It is likely, however, that this technology is nearing the limit of the potential reduction in chip size because of the linear nature of the circuit. Very small values of capacitance, together with the wide dynamic range of the signal, result in the need to handle very small electrical charges in which the movement of even a few hundred electrons becomes significant; as geometries are further reduced, this factor will limit the noise performance of the circuit.

Digital integrated circuit processes, on the other hand, still have the opportunity for considerable reduction of size before fundamental effects limit their standard of performance. Not only does it become cost effective to make an all-digital cofidec comprising some 10 000 gates, but the opportunity exists to introduce further signal processing as device geometries move to 2 μm and below. A further advantage of digital signal processing in this area is that the testing of the device is simplified. If the logic is correctly designed, the precise parametric testing needed for analogue devices is replaced by a rapid check of digital patterns, a correct response ensuring that the analogue parameters of the complete device will be correct. A codec device employing all-digital techniques was developed by BT for the Monarch digital PABX[5], and devices using similar techniques are now becoming commercially available.

The continuing increase in digital processing power referred to above permits integration with the cofidec of digital filters which synthesise the 2-wire input impedance and the 2/4-wire balance impedance of the line unit. Balancing the 2/4-wire converter in order to control echo and stability within the telephone network is a continuing problem: it has been found necessary to define three balance impedance networks in order to meet echo requirements. One impedance is used for the majority of lines, coupled with regulation of loss at the 4-wire point according to the loss of the subscriber's line. For subscribers' lines with high loss, however, further loss is removed from the 4-wire path, and echo loss is maintained by improvement of the trans-hybrid loss itself. In this case, one of two balance impedances is chosen depending on the predominant cable gauge in the local network. The introduction of a 2/4-wire converter with adaptation to the impedance of the local network eliminates the need for administrative action to identify and classify long subscribers' lines, and provides a better match to the majority of lines so as to enhance the overall echo performance of the network.



PCM: Pulse-code modulation

Fig. 4—Adaptive line circuit

Adaptive circuits are currently being studied, and Fig. 4 shows a functional block diagram of a line unit which includes such a system. The programmable 2-wire input impedance is synthesised by means of filtered feedback from the send path to the receive path whilst echo signals are cancelled by means of a filter connected from receive to send. A correlation is performed between the signals on the 4-wire send and receive paths and the resulting output is processed and used to control the response of the balance filter which emulates the transfer response of the echo path. In this way a satisfactory degree of cancellation can be achieved.

Considerable attention has to be paid to the nature of the echo path transfer response if the cancellation filter is to be designed for best results. The characteristics of this path are controlled by the impedance of the subscriber line, which varies widely depending on the gauge, line length and type

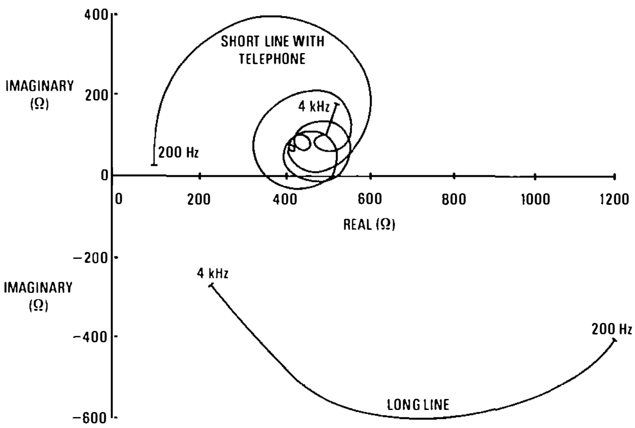


Fig. 5—Variation of line impedance

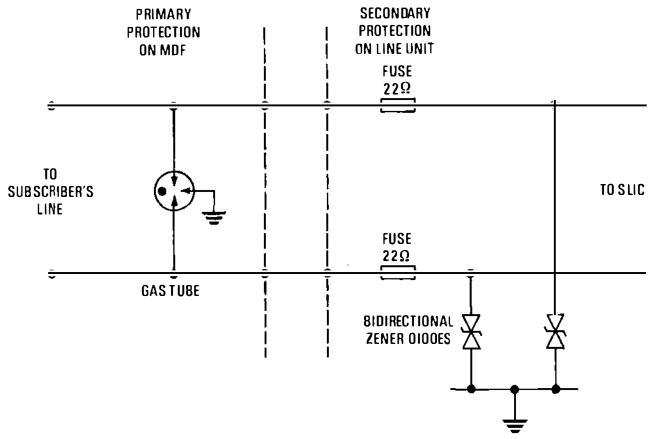
of termination. Fig. 5 shows an example of the range of impedances that may be encountered, and a study of this information coupled with a sensible trade between performance and complexity, can lead to a realistic solution.

The foregoing discussion concerning the SLIC and codec has shown that opportunities remain for the improvement of performance, reduction in cost and addition of extra facilities. It has already been pointed out, however, that less than half of the board area devoted to a line circuit is occupied by signal processing circuits. Significant savings in space can therefore be made only if the remaining areas, in particular the protection and switching components, are reduced in size.

Protection

Public network applications call for the subscriber line termination to be protected against direct connection to the public electricity supply and against induced surges of up to 5 kV. This performance is currently achieved by means of a combination of primary protection located at the main distribution frame (MDF) coupled with secondary protection at the line unit itself to remove the remaining surges and continuous overload conditions. These protection circuits interact, and it is important to ensure that the secondary components protect the SLIC correctly whilst allowing the primary components to divert the majority of the energy in a large induced surge.

Fig. 6 shows the circuit that is used on the line unit shown



MDF: Main distribution frame

Fig. 6—Line unit protection

in Fig. 2 and which provides protection to the full standard required. The secondary components are, however, bulky; furthermore, the whole card must be removed from service and returned to a repair centre for replacement of the fuse.

There is, therefore, an advantage to be gained if all the protection components are moved to the MDF: valuable area would be saved on the line card and the provision of a cheap throw-away module would simplify the repair of circuits that have suffered overload. Such a module has been developed; the circuit is shown in Fig. 7. The name *five-point* is derived from the need to make five electrical contacts to the module.

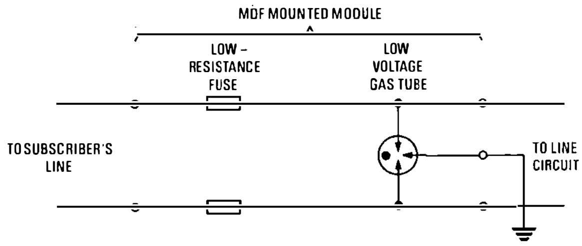


Fig. 7—Five-point protection

Any protection placed at the MDF must, of course, allow the ringing signal to pass unaffected by ensuring that the hold-off voltage of the clamp device is set well above the peak voltage that will be encountered on the line in normal use. Allowing for device tolerances, a maximum voltage of between 150 V and 200 V could therefore be passed to the SLIC during a surge. If the SLIC is not able to tolerate such surges, it must be protected at the line unit, and such additional protection must be very carefully designed to ensure that it does not interact with the MDF module; in particular, it is vital to ensure that the low-voltage line-unit clamps do not divert surge energy from the heavy-duty devices on the module. A better approach is to use a SLIC whose output stages are able to handle brief surges of up to 200 V, in which case no additional protection is needed and no space is wasted on the line unit.

Relay Replacement

A relay is an inexpensive component that offers ideal characteristics to the line-unit designer for use as a test-access or ring application switch. The combination of very low 'on' resistance, very high 'off' resistance and complete isolation of the drive circuit from the circuit that is to be switched is very difficult to simulate with electronic components. Relays do, however, suffer from the need for a large driving current and occupy a significant amount of space on a line unit. Replacement of these components by solid-state switch elements would reduce wasted board area and eliminate the final electromechanical component from the line interface.

BTRL is currently involved in the design of solid-state switch elements for use on a line unit; the diagram of a typical application is shown in Fig. 8. In this circuit, change-

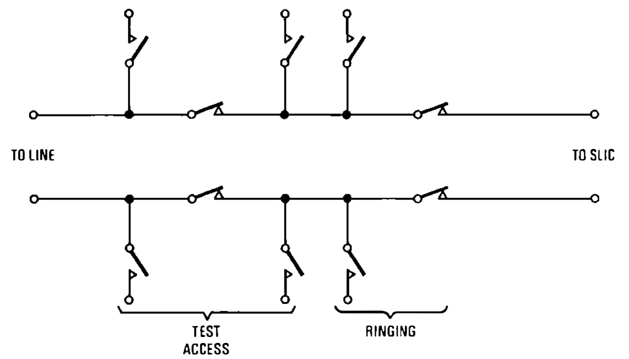


Fig. 8—Line unit solid-state switch

over relay contacts are replaced by a switch element in series with the subscriber's line, and a shunt element which connects to the test bus or to the ring supply. This arrangement places constraints on the design of the series elements, which must be of low resistance and must not significantly affect the impedance balance about earth of the line circuit. Typical values for the series elements are 10 Ω maximum, with A-wire and B-wire pairs matched within ± 1 Ω.

The design of solid-state switch elements also interacts with protection of the line circuit. Not only must the switches withstand any high voltage induced in the line, but they must also handle the large currents which will flow if extra clamping elements are introduced on the line card to protect the SLIC.

Once the problems of protection and relay replacement are overcome at a satisfactory price, the last bulky component can be removed from the line unit and a much higher packing density achieved.

EQUIPMENT PRACTICE AND SYSTEM CONSIDERATIONS

Preceding sections have shown that there is still a considerable amount of work to be done to reduce the cost and size of the analogue interface. Modern SLIC and codec components will help to reduce cost and to improve performance, whilst the replacement of relays with semiconductors and a change in protection arrangements will release wasted board area. It will then be possible to mount 16 or more circuits on a board with dimensions of that shown in Fig. 2. However, this trend might not be desirable from a system point of view. Such an increase in the number of lines per plug-in module may introduce power dissipation problems and, perhaps more important, could be undesirable for administrative reasons. In the event of a fault, service is denied to 16 customers while the board is exchanged and the whole costly unit has to be returned to a service centre for repair. Furthermore, in small exchange systems, the use of large incremental units for growth can result in expensive over-provisioning.

It will not be long before the BORSCHT functions can be performed by two integrated circuits: a high-voltage line interface together with a digital processor, possibly coupled with solid-state components for test access. This change from a mixture of miniature devices and bulky components to circuits consisting of only a few miniature electronic components means that full use can be made of surface-mounting techniques to reduce the overall size of a line circuit. This allows production costs to be reduced by the use of automation, and repeatability and reliability of the circuit to be improved. These advances in turn lead to the possibility of producing the line circuit as a small replaceable module which will help to eliminate the practical problems mentioned above.

The improvements in line-circuit components outlined above will be of value in improving the performance and reducing the cost of conventional line units. Taken further, however, a change in the basic module size would call for a study of the mechanical shelf units that provide the foundation of the system. Changes to the structure of the system may also be beneficial, with shared controllers being replaced by per-line dedicated controllers, each having secure access to the next control layer.

CONCLUSION

Cost-effective line unit designs that are suitable for use in the public network now exist, but do not necessarily rely on integrated SLIC products. Introduction of integrated SLICs and advances in codec design will help to enhance the performance and reduce the cost of the analogue interface, but the biggest space savings can be produced by the development of solid-state replacements for protection circuits and relays. It is interesting to note that the elimination of a relay can open the way for improvements in interconnection, mechanical equipment practice and exchange control structures.

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Biography

John Ames joined BT in 1967 as a Student Apprentice and spent a year in Chester Telephone Area before beginning studies at Birmingham University. On graduation with first-class honours in Electrical and Electronic Engineering, he joined the digital switching division at BTRL working on high-speed logic and the problems of clock distribution in large digital systems. During 1974/75, he obtained an M.Sc. in Telecommunications at the University of Essex and returned to BTRL to work on the design of switching systems, including the UXD5 rural exchange. In 1979, he was promoted to lead a new group concentrating on the design of analogue line interface circuits. In 1983, he was promoted to his current position of Head of the Advanced Interface Realisation Section dealing with all aspects of analogue and digital interfaces with digital exchanges and with the design of advanced codec components.

ARSCC/E—Administration of Repair Service Controls by Computer

Part 1—Background to Computerisation and System Design Philosophy

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This article describes a computerised system used for the administration of British Telecom's repair service controls (RSCs) which is now in widespread use. For convenience, this article has been divided into two parts. Part 1 begins by discussing the historical background to computerisation, and goes on to describe the design philosophy of the system and how the system is structured to model the operation of an existing manually-administered RSC. Part 2 will describe how customers' fault reports are handled by the system, and the management facilities available. Part 2 will also consider technical aspects of the overall system and the hardware used, and will conclude with a discussion on the implementation programme and the strategy for future development.

INTRODUCTION

Until the first computerised administration system for repair service controls (RSCs) opened in Edinburgh, in the early summer of 1982, the procedures and methods for receiving, diagnosing, handling, clearing and analysing customer-reported faults in British Telecom's (BT's) RSCs had remained largely unchanged for 50 years. The introduction of *administration of repair service controls by computer* (ARSCC) represented a significant milestone in computing in BT because it was the first truly interactive on-line transaction processing system in the business. This article traces the history of the development of ARSCC/E the largest of three administration systems in current use in BT, and describes its design philosophy and the methods employed to implement the design.

NON-COMPUTERISED REPAIR SERVICE CONTROLS

Organisation

Customers report difficulties with their telephone service to an RSC by dialling the national code 151. The detailed organisation of RSCs varies, but can be considered to comprise the following major functions:

(*a*) reception of complaint;
(*b*) diagnostic testing to determine the existence and nature of any fault;
(*c*) the distribution of faulting work to, and control of, field engineers;
(*d*) records maintenance; and
(*e*) management and supervision of the RSC.

Reception Function

The fault reception officer (FRO) is the initial interface with customers wishing to report difficulties with their telephone service. FROs answer calls on incoming 151 circuits and record details of customers' complaints and difficulties on dockets, which are then passed on to other functions within the RSC for further processing as required. FROs are additionally required to answer customers' queries on the progress of outstanding complaints and may receive queries on other matters not related to the repair service.

Diagnostic Testing Function

The initial fault verification test of a customer's line and equipment is normally carried out when the complaint is received. This test is limited in its scope and is intended to determine that a fault condition actually exists.

Advantages of immediate testing, especially with the customer on the line, include the determination at the point of reception of many right-when-tested (RWT) reports and station equipment faults. More extensive tests may be required at a later stage if the fault condition is in the local line plant, in order to localise the fault more accurately; this is usually left to a skilled diagnostic testing officer.

Any test results, whether determined at reception or diagnostic test, are included on the report docket, which is then passed to the fault distribution officer (FDO).

Fault Distribution Function

The FDO is responsible for progressing the clearance of fault reports by controlling, and liaising with, field engineers and other maintenance groups on the issue of work, and receiving and recording fault clearance information. The FDO is also involved in co-operative testing with field engineers, in order to localise the more elusive fault conditions.

Records Maintenance

A card containing the customer's name and address, apparatus and line plant details, together with fault history, is held in the RSC for each customer's installation serviced by the RSC. More complex installations such as PBXs have a pack of information cards covering details of the installation, line plant and extension equipment, as well as any special

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services records associated with that installation. The smallest RSCs could hold as few as 20 000 such cards, the largest as many as 300 000.

At some time during the processing of the fault docket, the relevant record card is extracted from the card file and associated with the docket, accompanying it through the remainder of the fault clearance process. It is from this card that the necessary engineering information is extracted relating to customer facilities and circuit routeing. When the fault is cleared, the details are recorded on both the card and the docket, the former being refiled and the latter retained for analysis.

Changes to the permanent information held on the card are made by records officers when the RSC receives advice from the sales and service offices. These advices result in additions, deletions and amendments to the card file.

Supervision and Management

As well as the normal personnel-management function expected of the RSC manager, there exists the need to determine that the RSC is performing satisfactorily in terms of achievement of fault-clearance and quality-of-service targets. This monitoring function is carried out by gathering data from the RSC on fault durations, nature of cleared faults etc., largely by analysis of the closed fault dockets, and collating the information manually on to forms suitable for absorption by local management.

The RSC manager also has access to fault-progress and fault-history information, on report dockets and record cards, in order to answer complaints from customers and queries from other service departments within BT regarding the repair service.

PROBLEMS AND DIFFICULTIES WITH THE MANUAL METHOD

Inadequate Information at the Workstation

Customers' perception of the repair service is largely based upon the attitude and efficiency of the FRO. One of the major criticisms of the repair service has traditionally been the length of time taken to answer calls on 151 circuits; this is currently monitored and published as key productivity indicator (KPI) R7. The current national target is that 85% of all calls on 151 should be answered within 25 s. The ability of the FRO to meet this target is determined by the range and duration of the many support duties that need to be performed. Lack of access to any form of permanent information record at the reception workstation limits the ability of the FRO to deal rapidly with the initial contact with the customer. In order to determine this information, the FRO must leave the workstation, thus extending the transaction time with the customer and reducing availability as far as the 151 answering service is concerned. Because of the lack of in-hand report information available at the reception workstation, difficulties also arise in advising customers of fault progress and clearance prospects, both at the time of initial report and when subsequent enquiries are made. Consequently, firm arrangements for access to customers' premises cannot be made, and this leads to abortive visits and an indifferent service.

Records Problems

The physical size of the card file causes accommodation, organisation and staffing problems. Retrieval of the customer's record card is slow. It is available to one person only at a time and is sometimes lost or misfiled. Cards, being handwritten, are often difficult to read and have a short life if the installation concerned has a high fault rate. Errors and out-of-date information on the record card are common. Unless a common coding system is used, the fault-history information is of little value for analysis.

The cost of maintaining the record cards is high in relation to their value, both in the clerical effort required and the accommodation costs of the records themselves. Analysis of the records, to provide information for reliability exercises and other *ad hoc* enquiries, is extremely difficult and time-consuming, and is therefore rarely done in practice. For this reason, the RSC manager cannot hope to optimise the organisation of the RSC or provide much meaningful information about plant performance.

Communication Problems

As RSCs have developed, they have tended to centralise, to take advantage of the economies of scale. This centralisation implies higher staffing levels, which result in discrete functional groupings within the RSC. In terms of RSC efficiency, the ability for officers to communicate effectively is lost when the number of staff exceeds about 10, because it becomes physically difficult to communicate between, say, the reception and distribution groups. If the only means of carrying such information is a single document, then the ability of any individual to respond effectively is governed by whether access to that document is available when required, or by access to the person currently having the greatest knowledge of the problem. In a large RSC, both these alternatives become very difficult to achieve.

Dissatisfaction

The control of fault clearance work is, of necessity, a largely administrative function, although a degree of technical and local knowledge is essential for it to be effective. The existing manual administration methods in RSCs and the ever-increasing need for performance information overburdens the control engineers to the point where their engineering expertise becomes of little value, because of the lack of opportunity to use it. This in turn leads to inadequate fault diagnosis and misuse of field engineers with the consequential increase in costs that an unnecessarily high rate of abortive visits causes. The result is customer and staff dissatisfaction, the customers perceiving inadequate or inefficient service and the control engineers being too overloaded with clerical and administrative duties to be able to use their skills to do anything about it.

EARLY MOVES TOWARDS TACKLING THE PROBLEMS

Systems Analysis

Between 1972 and 1976, the Engineering Efficiency Division of the Management Services Department of Telecommunications Headquarters undertook a series of studies related to RSC organisation and methods, sponsored by the Service Department. The outcome of these studies was a series of reports highlighting the difficulties described above. The inescapable conclusion to be drawn from the recommendations contained in these reports was that some form of computer assistance was required in RSCs, although doubts were expressed in terms of the cost-effectiveness of a machine solution with the technology available at that time.

At the same time, studies being undertaken for Service Department by the Computer Division of Management Services were investigating a means of encoding and capturing fault clearance data for subsequent mechanical analysis. This scheme, known initially as *data processing for the repair service* (DPRS), involved the use of an optical-mark-read docket to replace the existing manuscript docket; the new docket was selectively marked at each stage of the progression of a fault report by scoring through predefined encoded data boxes. It was intended that, by collecting and analysing fault clearance data in this manner, the onerous tasks of maintaining fault histories and extracting the national data required for the production of published performance indicators could be removed from the RSC. A feasibility report published in 1977 resulted in a field trial at Oxford and East Grinstead RSCs, which commenced in 1978. The dockets themselves were batch processed by using specialised docket-reading machinery installed for the purpose.

The outputs from this process, which ran on a weekly basis, included a fault history on microfiche; a weekly and cumulative performance report (A29), for subsequent reinput into the national performance-monitoring report (A51); and exception reports, to highlight high repeat-fault incidences. As a by-product, a database was configured under RAMIS (Rapid Access Management Information System), a proprietary database interrogation package, with a set of library procedures to extract useful subsidiary information on an *ad hoc* dial-up basis.

Availability of Hardware

At about this time, a team of senior managers from Service Department visited the USA on a general fact-finding tour of North American telecommunications administrations and were impressed by the penetration of minicomputers into many of their spheres of activity, together with the comparative ease of implementation and relatively low cost of these machines. Subsequent to this visit, the Repair Service Policies and Procedures Section of Service Department was invited to put forward proposals for the use of minicomputers in the repair service; after an initial statement of intentions had been produced and accepted, a system definition team was formed.

Work commenced on the preparation of the Statement of Requirements for ARSCC/E in March 1978 and the first working issue was published in November of that year.

Mainframe or Mini?

Whilst this work was proceeding, discussions were taking place with regard to the realisation of the system. Although the original impetus for system development was based upon minicomputers, the business had a high level of investment at that time in large mainframes, strategically sited throughout the UK, and this, coupled with the expertise available in-house on these machines, argued a strong case in favour of mounting the proposed application upon them. The Computer Assistance for Service Co-ordinating Committee (CASCC) concluded that, despite the apparent advantages of using the in-house mainframe capacity, the repair service function was sufficiently sensitive to warrant dedicated, locally controlled and operated machinery, to be available 24 hours a day, 7 days a week. This could not be easily achieved in the mainframe environment, where several staff associations were involved and where the trend was away from working unsocial hours. Additionally, the proposed mainframe solution implied that ARSCC/E would be only one of many concurrent applications, and that operational difficulties caused by any one of these systems could seriously disable the repair service over a wide area. Consequently, the mainframe proposals were dropped in favour of local minicomputers operated by those who would be dependent upon them—the RSC staff themselves.

Buy in or Develop?

Once the decision to use minicomputers had been made, the question of which was the most rapid route to the implementation of a trial system needed to be answered. Initial studies seemed to suggest that the quickest route might be the adoption of an existing package designed with the telephone repair service in mind, sourced from the obvious place—the USA. Several packages existed at that time, but all of them had been designed by specific administrations and suited their particular needs. This course of action implied difficulties because the working disciplines imposed by the design philosophy of these systems was sufficiently alien to the current working methods and policies in the UK to require major re-writing of the software, either by BT or by the originators. Additionally, it would have been conditional upon the acceptance of such a package that a specific machine, not necessarily the best choice in terms of cost and performance, would need to be used to support it. This, coupled with the dependence that BT would have upon both the software and hardware suppliers, led CASCC to conclude that there was no short cut available in the form of a ready-made software package from any source.

Invitations to tender were issued for a suitable minicomputer and supportive software tools for the ARSCC/E development; this resulted in an initial order being placed with Honeywell Information Systems for a small number of machines in its Level 6 family of minicomputers, the Level 6/43. A dual-machine configuration was installed in Cardiff, as a software development tool, during 1980. Additional dual machines were installed during 1981 at Edinburgh and Eltham (in London) RSCs, which were chosen for the field-trial sites, Edinburgh because it was at that time the largest RSC in the UK, and Eltham because of the special interest that British Telecom London had in an early solution, in view of its politically and commercially sensitive location.

Choice of Programming Language

The decision about which high-level language to use had to take several important factors into account. The most significant of these was the availability of expertise within BT which, at that time, was generally COBOL-oriented. Another major factor to consider was that any national implementation of the system should, ideally, involve multiple-sourced hardware, and therefore a transparent source code should be used. As COBOL had in the past been generally accepted as the correct vehicle for such systems, and is generally supported by most hardware manufacturers, it appeared that this would be the correct route to follow. COBOL, however, had several significant disadvantages in that it was far from ideal as an interactive transaction-processing language: it required many transaction-handling processes to be written from scratch; it did not in itself support a database manager, which was considered to be essential in a prototype system; and it was relatively extravagant in terms of the quantity of source code required to achieve the desired result, which would result in lower programmer productivity.

As an alternative, and in compliance with the rapid implementation policy which led to the decision to use a minicomputer, a proprietary software development tool needed to be considered.

A major factor in the decision to purchase Honeywell equipment was the proprietary system development language SCREENWRITE. This language was designed by Honeywell to optimise the use of their own Integrated File System (IFS) and Transaction Processing System (TPS6). The value of SCREENWRITE lies in its compatibility with both the operating system (GCOS6 MOD400) and TPS6, together with the fact that it is easily learnt. In order to gauge the relative efficiency of such a tool, it is worthy of note that the ratio of source code required to be generated for an identical system written in COBOL and SCREENWRITE is estimated at 1·8:1, virtually halving the programmer effort and subsequent maintenance load.

SCREENWRITE was duly chosen as the source-code language and, after an initial training and familiarisation period, serious coding commenced in February 1981. The first release of software for Service Department trials, designated *Release 1.0*, was loaded on the Edinburgh machine in January 1982. This initial release comprised 20 000 lines of system-tested code, produced by a team of 12 programmers over a period of 10 months.

A Working System

Although Release 1.0 satisfied much of the Statement of Requirements for ARSCC/E, it became evident that many lessons needed to be learned, both in terms of the perceived elegance of the product and the realisation of theoretical ideas. As a result of trials, the software was advanced to Release 3.0, and it was with this release, in June 1982, that Edinburgh RSC took on machine-assisted processing of the complete RSC administrative function.

ARSCC/E—DESIGN PHILOSOPHY

Fundamentals

From the outset, it has been recognised that ARSCC/E should support the largest RSCs and should be, as far as possible, a fully interactive processing system, with all fault-progression transactions taking place as a dialogue between the control officers and the machine via visual display units (VDUs). This philosophy ensures that accurate data is collected at all stages of the fault clearance process and therefore full and current information is always available to all users, and that subsequent analyses of the collected data are comprehensive and accurate.

This design concept requires a highly sophisticated system, capable of supporting as many as 100 workstations servicing up to 300 000 reports per annum, providing comprehensive data displays on all aspects of the operation of the RSC, and with response times in the order of 2 s for the majority of transactions.

Although the objective of each RSC in the UK is identical—to deal with complaints from customers as quickly as possible within reasonable financial constraints—the means of achieving this goal varies considerably according to local conditions. Because of these differences, ARSCC/E has had to be designed as a flexible administration system to suit the many different local arrangements encountered.

During the design phase of ARSCC/E, the opportunity arose to revise RSC procedures to take full advantage of computerisation. It was felt, however, that such a drastic single-step change would be unacceptable to the end users of the system and, therefore, that the initial approach should be in the form of a mechanised duplication of existing methods, with design features to allow optimisation of procedures as the use and experience of the system revealed inadequacies in the manual methods.

To more fully understand the way in which ARSCC/E mirrors the existing manual methods, and to appreciate the requirements for organisational flexibility, it is helpful to review current RSC organisation and practice.

Organisational Differences Between RSCs

The functions that are required to be performed in RSCs have already been outlined and are implemented in a variety of ways to suit local conditions and staff agreements. The organisational differences found between RSCs and the implications for the functions performed can be described in terms of a limited number of working methods, which are described in the following paragraphs.

Full Territorial Working

Under full territorial working, the reception, test and distribution functions are combined into one duty, which deals with one or more telephone exchange areas. The territory may be served by more than one control officer, depending upon the complaint calling rate and the number of faultsmen controlled. It is generally advantageous with this arrangement in a non-computerised RSC to divide the card file territorially and to place the territorial divisions of the file in close physical proximity to the control officers.

Territorial Reception and Distribution

Under this arrangement, one or more reception officers service a group of incoming customer-complaint lines from an identifiable territory, usually based upon one or more exchange areas. Several territories may exist, each having its own territorial reception group. Similarly, these territories are serviced for distribution purposes by one or more distribution officers. The reception and distribution officers together form a team servicing the same territory, although the reception and distribution elements of the job are carried out by different individuals. The diagnostic test function may be vested either upon the reception officer or the distribution officer. The card file under these circumstances is normally located centrally, and access is therefore relatively inconvenient for everybody.

Anonymous Reception

All complaint lines are commoned into an anonymous group, answered by a single team of reception officers. Reports so received are routed within the RSC to the appropriate territorial distribution group, via a diagnostic testing function if required, for progression and clearance. Once again, the card file is centrally, and therefore inconveniently, located.

Fault Report Handling

Whichever organisation is present in the non-computerised RSC, the need exists to record and progress fault reports (Fig. 1). In most RSCs, this is achieved by means of the fault docket, which is completed at reception. The docket is used to record the telephone number of the reported fault,

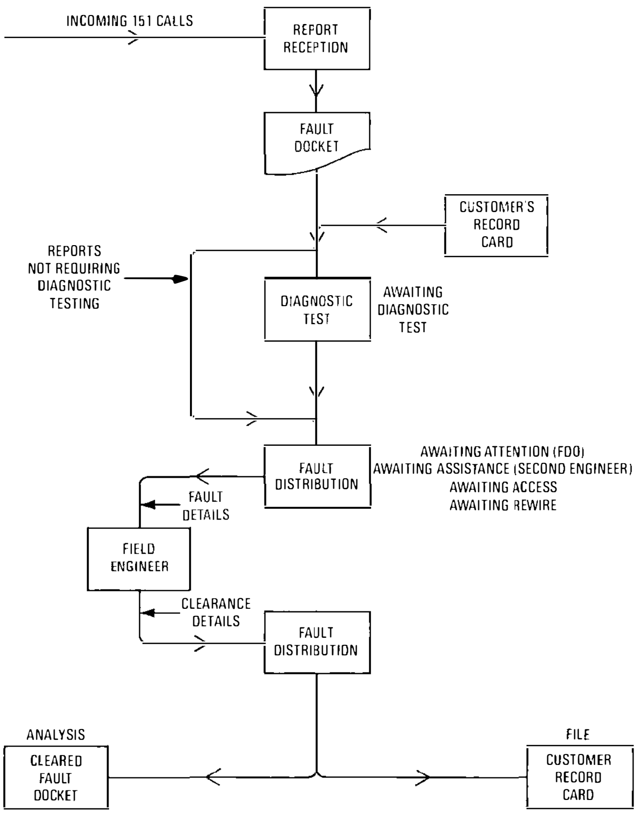

Fig. 1—Report handling process

together with the time and date, the nature of the complaint, any initial test result, appointment or access information, and whatever other information can be gleaned from the customer that may be useful in clearing the fault. The reception officer may also have need to refer to the customer's record card, upon which is recorded details of the installation, the circuit routeing, and a brief fault history.

At some stage in the progression of the report, the docket and record card are brought together, and remain so until the fault is cleared. At this time, the docket is combined with others and put aside for analysis purposes. The record card is annotated with the details of the cleared fault and returned to the card file.

During the progression of the report through the RSC, it passes through several functions. If the report is diagnosed adequately at reception, it is passed directly to the appropriate distribution duty for customer apparatus and lines or external work for subsequent issue to field staff. The more complex reports may require further testing by a skilled diagnostic tester before the location of the trouble can be determined. In some cases, it is necessary to localise the report by co-operative testing with either exchange or field staff. Many reports are found to be RWT and are cleared without issue.

As each report progresses through the RSC, it remains with the function dealing with it for some period of time. To group together reports awaiting similar processes, local filing arrangements exist at each workstation, generally referred to as *pigeon-holes*. Many such pigeon-holes exist, identifying, for example, reports awaiting further test, awaiting distribution, in hand with field or exchange staff, or cleared awaiting refiling. This list is far from exhaustive and arrangements vary greatly from one RSC to another.

In general terms, the administration of the RSC can be considered to be based upon a dynamic filing system for customer information, fault report records and customer fault history. The variances encountered in the organisation of the dynamic file, represented by the variety and quantity of pigeon-holes, typify the differing organisations within RSCs. Because the file is dynamic and because no easy means of recording the location of out-of-file records exists, the number of pigeon-holes and the time that records remain within each is a primary indication of the effectiveness of the organisation in terms of the population of customers it serves.

Realisation of the Design Requirements

In order to provide the correct environment for the administration of the repair service, ARSCC/E generates and maintains a model of the RSC organisation, through which fault reports can be progressed and monitored to clearance. During the processing of fault reports, the system gathers statistical information which can be used to monitor the effectiveness of the organisation that the model represents, identify weaknesses and suggest ways of modification to achieve improvement. The model can itself be modified as optimisation of the organisation takes place.

In order to describe the system, it is convenient to consider it in terms of subsystem modules, although the actual software is not necessarily modularised as described.

SUPERVISION AND MANAGEMENT SUBSYSTEM (SMSS)

The means by which the RSC model represented by ARSCC/E can be tailored for a given requirement, and subsequently modified, are provided within the supervision and management subsystem (SMSS). Control variables, known as *control parameters*, describe the RSC organisation and are used by the system to build and control the model.

Lists

ARSCC/E is essentially a mechanised dynamic filing system. In order to identify the pigeon-holes or nodes of the dynamic file the system provides identifiable nodal elements, known as *lists* (Fig. 2). All lists can be displayed on the workstation VDU, and are analogous to the pigeon-holes found in the manual method. As the manual system has differing requirements for different nodes in terms of report processing, so ARSCC/E provides different types of lists, with features specific to the required process at the node.

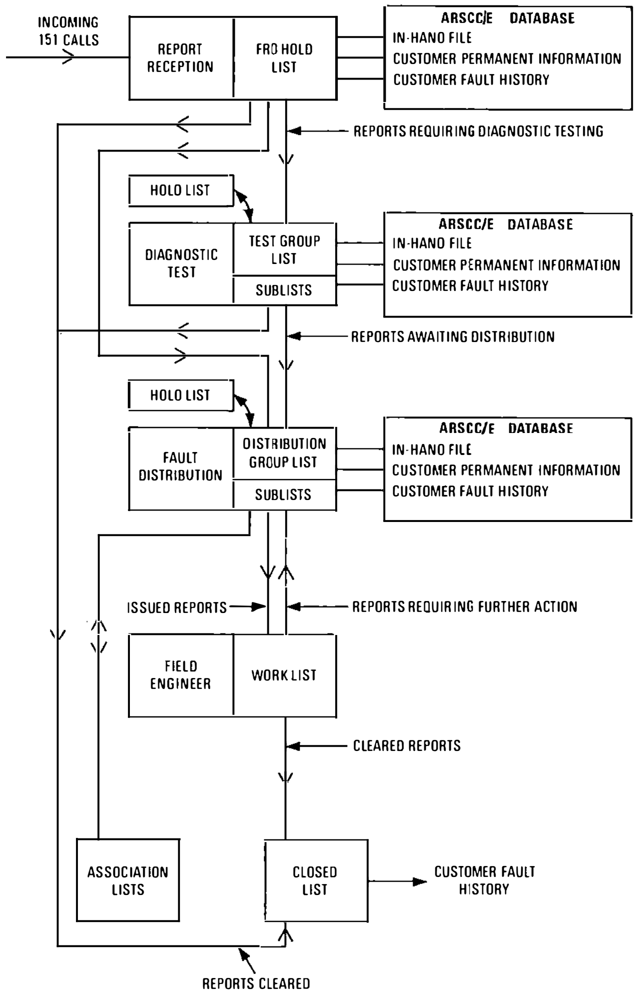

Fig. 2—Basic list arrangements

Fault Report Records

The lists themselves comprise a collection of entries representing *fault report records* (FRRs), which replace dockets in the manual method. These FRRs can be conveniently described as 'electronic dockets', and it is this description which results in the suffix *E* in the acronym *ARSCC/E*. The FRR is the prime carrier of fault progression data, and the list provides a means of grouping FRRs according to functional requirements.

It is important to note that the FRRs themselves are held in a common 'in-hand file' and, as such, are available to all users for inspection and update at all times. This feature overcomes many of the disadvantages of the manual method.

The progression of FRRs through the various functions in the RSC is achieved by moving the entries relating to them between the lists. A description of each list type and its implementation within the SMSS is described below.

Hold List

As FRRs are progressed through the RSC, it frequently becomes necessary to hold them. Examples of this requirement include the need to update customers' details at a later stage and intermittent co-operative testing. The common requirement is that the FRR is held by an individual because that individual has a unique knowledge in respect of the furtherance of that FRR. As such, it is likely that removal of an FRR from the individual prevents that unique knowledge from being applied to the clearance of the report. To fulfil this requirement, ARSCC/E provides the *hold list*.

Each user of the system who performs either a reception, test, distribution or supervision function within the RSC is allocated a hold list at user registration time, which is identified by the user's initials wherever possible.

Group List

For the purposes of efficient organisation, it is generally convenient to group an FDO with a team of field staff. The FDO controls the work done by the field staff, and, as the number of field staff depends on the size of the territory they service, it may become necessary to divide the FDO load between more than one individual. Similarly, there may be a need to divide the diagnostic testing into more than one group, depending upon load and test access requirements. A third grouping, to be found in all RSCs, comprises the manager and his Technical Officer with Allowance (TOA). Between them, they control and co-ordinate the clearance of the more difficult FRRs. The exact nature of the division of this work is very much a local arrangement.

In order to provide a source of work for these groups, ARSCC/E allows for an identifiable node, known as the *group list*. FRRs represented in a group list are 'awaiting attention' by that group. Each of the individual users associated with that group are responsible jointly for processing FRRs in the list, according to priorities defined locally. The list-management software has facilities to order the entries within the lists, and this ordering can be considered by the user processing the list as a guide to the order in which the work should be done.

Group Sublist

The group list described above is a major node in the organisational model. Several group lists will exist in every RSC and the majority of FRRs being processed will be distributed between these lists. A disadvantage of screen presentation of the contents of these lists is that it is not possible to present the required information for more than 10 FRRs on the screen at any time; this presentation is known as a *page*. A typical group list can contain any number between 3 and 20 pages, typically.

As a primary function of the FDO is to scan these FRRs regularly to achieve a conception of the nature and size of the outstanding workload, it has been found necessary to provide some means of subdividing the group list into more manageable groupings, known as *sublists*. The sublist can be considered as a tool for excluding from the displayed group list those FRRs that are not the current concern of the FDO, thus reducing the display to more manageable proportions.

ARSCC/E provides, within the SMSS, a means of generating multiple sublist identities for each group list, together with the qualifying data related to that sublist.

FRRs qualify for inclusion in a sublist by the value of the data contained within them; that is, the exchange name, the class of service of the installation and the fault localisation code.

Consider an example where a distribution group requires a sublist for each exchange area as well as a sublist for underground (UG) faults covering the entire distribution group territory. In this case, an FRR would be included in the sublist for its exchange whether or not it is an UG fault. If that FRR is localised UG, it would also be represented in the UG sublist, together with all other FRRs relating to other exchange areas localised UG. FRRs localised other than UG would be excluded from the UG sublist.

In terms of the organisational model, the sublist does not represent a node, rather a convenient means of examining the contents of the node.

Work List

As the FDO processes FRRs within the group list, it becomes necessary to transfer them to other nodes representing the field staff. Such a node is known as a *work list*.

FRRs in work lists can have one of two states, preallocated or issued. A preallocated FRR is one which the FDO has decided will be dealt with by the field engineer represented by the list, although the engineer will not yet know of the report. An issued FRR is one which has been communicated to the engineer and is currently receiving attention in the field.

Work lists include specific header data relating to the skills of the field engineer, termed *discipline codes*. They also include the identity of the field maintenance group (FMG) to which the engineer works. ARSCC/E also provides for the registering of messages to the field engineer, which can be added to a temporary display area in the list header. This feature replaces the notes left in the faultsman's pigeon-hole in the manual method.

Work lists are associated with group lists within the system model and, together with the hold lists of the FDOs, comprise the *distribution group*. Work lists are identified, as far as is practical, by using field engineers' initials.

Association List

All RSC organisations require, in addition to the lists already described, nodes which are global to the RSC rather than local to a distribution group. Examples of such nodes are AWAITING REWIRE, NO ACCESS and OUTSTANDING MAINTENANCE. Many such nodes will exist and they will differ greatly in their number and use from one RSC to another. In order to provide such nodes within the system model, ARSCC/E provides an additional list type, known as the *association list*.

These lists can be generated by the manager using facilities provided within the SMSS, and can be temporary, as in the case of a cable breakdown, or permanent. They include a specific title, inserted when they are created, describing the contents of the list. Their use within the RSC is intended to allow FRRs with a common factor to be gathered together, such as the examples already mentioned. They may be effectively used to 'park' FRRs which are awaiting some stimulus for their reactivation; for example, the returned no-access card (A108).

Up to 100 association lists can simultaneously co-exist within the system model, allowing for a high degree of tailoring to suit individual RSC organisational requirements.

List Identification and the Movement of FRRs Between Lists

For the system model to be effective, a means of transferring list entries between nodes must be provided. This is termed *allocation* and the identities of the nodes, or lists, are known as *allocation codes*.

All reception, test and distribution (RTD) functions are provided with a system command to reallocate FRRs between lists. The effect of the use of this command is to delete the entry relating to the FRR from its current list and insert the entry into the list identified by a parameter associated with the command. Thus the FRR is effectively moved between nodes within the model.

The reader will recall that the FRR itself does not move. In this respect, there is a significant difference between the system model and the manual method, in that any user processing at any node can view any FRR at any time, regardless of the node in which it currently resides. This is one of the major advantages of the model, as it provides rapid and comprehensive information on the state of any in-hand FRR regardless of its nodal location within the RSC. The model eliminates the need for a search between nodes by retaining all in-hand FRRs in the common in-hand file. Therefore, the lists described above can be considered to be functional indexes to the contents of the in-hand file rather than the contents themselves.

Tailoring ARSCC/E to the Local Organisation

When an ARSCC/E system is installed in an RSC, no functional lists exist. One of the primary tasks required of the manager is to identify the nodes of the model in terms of list types and identities. It has been found from practical experience that this exercise itself highlights weaknesses in the manual organisation which may be eliminated during implementation: the process enables the manager to assess load balance between the distribution groups as well as indicating the need to rationalise in terms of traditionally accepted long-standing arbitrary divisions of the organisation which have little or no justification in current circumstances.

Association lists are identified in this analysis, any relationship between groups and permanent association lists being indicated. Sublists are also planned and indicated at this time, in full consultation with the FDOs that will be using them. Group- and association-list identities are chosen to be meaningful and readily associated with the organisational node to which they relate. Work list identites are chosen to be as far as possible the initials of the field engineer, or some locally agreed nickname, such as 'JOE'.

Under certain circumstances, it may be more appropriate to use a group list instead of an association list for certain requirements where the sublist facility may be useful. There is no system restriction on the use of group lists in this manner.

The manager is also required to identify all users of the system in terms of their initials (three unique alphabetic characters), the functions they are required to perform on the system and an initial security password to enable them to log on when the system becomes active.

Other preparatory work includes the compilation of a complete list of exchanges served by the RSC, their subscriber trunk dialling (STD) codes, the locally used abbreviation for the exchange name and the number ranges for each exchange. Additionally, the manager must furnish a maintenance exchange code for each exchange. This code comprises the STD code, less the leading zero, and includes sufficient digits from the customer number to uniquely identify the exchange unit in a linked-numbering scheme, for statistical purposes.

Tailoring ARSCC/E for Multiple Implementation

ARSCC/E allows for more than one RSC to be supported by the same computer system. This concept is termed *multiple implementation* (MI). The data described above is therefore collected for each RSC (known as an *operational unit* (OU)) to be served. Some of the data, known as *overall control parameters*, are relevant to the entire system. The remaining data are specific to each RSC in the MI and are termed *local control parameters*. Under MI, an additional managerial function is catered for, known as the *system administrator* (SA). In most cases, the SA is nominated from among the RSC managers that the MI serves, generally the one whose RSC is co-located with the computer system.

Control Parameters

Organisational model building therefore comprises two phases. Firstly, the designated SA is required to set up the overall control parameters. When this is done, the individual RSC managers (S2 users) can configure their own environments. These control parameters are illustrated in Fig. 3 and are described below.

The functions of the overall control parameters are as follows:

(*a*) *System and Operational Unit Identification* These parameters enable the SA to include the name of the system, the names and processing codes of each OU within the system and the identities and initial passwords for each RSC manager and TOA, thus enabling them to log into the system to set up the local control parameters for each OU.

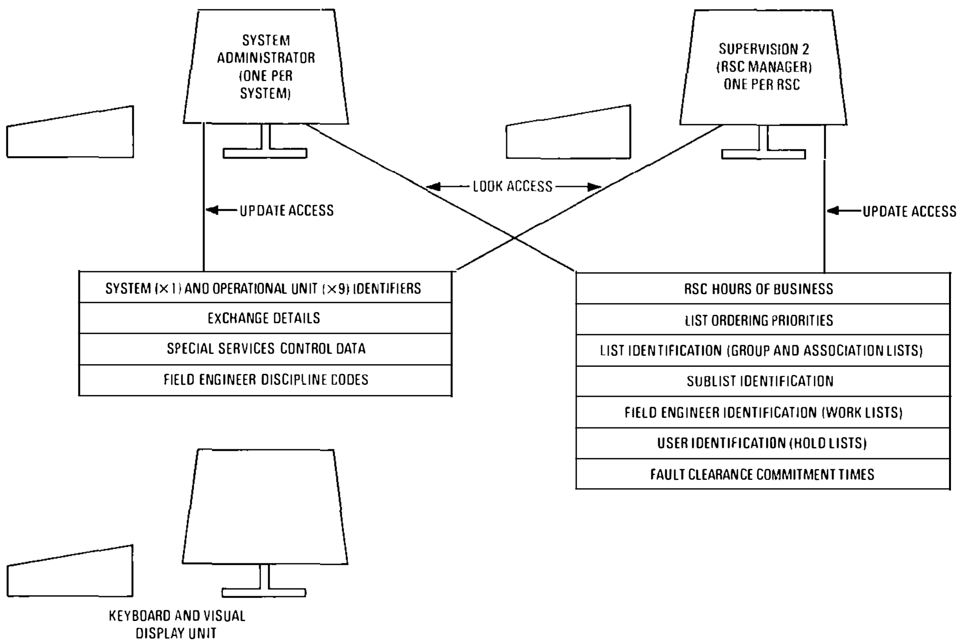

Fig. 3—System control parameters

(*b*) *Exchange Details* These parameters enable the SA to set the exchange details for up to 430 exchanges on the system on a global basis. As well as the exchange names, STD codes, maintenance codes and ranges, the SA is required to identify which OU is to service each exchange. This enables data vetting on entered telephone numbers and automatic routeing of FRRs between OUs.

(*c*) *Special Services Control Data* These parameters include the identities of the fault reporting points (FRPs), circuit control codes and special services fault-clearance commitment times.

(*d*) *Field Engineer Discipline Codes* These parameters are used by each RSC manager to describe the field engineers in terms of their skills. Up to 20 discipline codes are allowed, any combination up to five of which may be used when the work lists within each OU are set up.

The local control parameters are available to each of the RSC managers to tailor the organisation of their own OUs. These control parameters are described in the following paragraphs:

(*a*) *Basic OU Parameters* These include the RSC opening and closing times, for the purposes of assessing jeopardy reports†, and the list ordering priorities. FRRs are ordered in lists according to one of 55 priorities associated with the installation service code. Within the priority groupings, FRRs are ordered according to report time, with the oldest at the top. All lists are ordered according to this priority system.

(*b*) *List Identities* These parameters represent the list identities to be used within the system. They identify the allocation codes of all test group lists, distribution group lists and supervisor group lists as well as the association lists. An opportunity to insert descriptive text for association list headers is provided.

(*c*) *System User Identification* These parameters represent the identities and functions of the intended users of the system. User functions include any combination of one or more of R (reception), T (test), D (distribution) and REC (records). Alternatively, the function can be ENQ (enquiry) or ENQL (enquiry with lists), which provide limited 'look only' facilities to users external to the RSC. For each user declared within this option, a hold list is automatically created with the same identity as the user.

† Jeopardy reports are explained fully in the section on the management statistics subsystem in Part 2 of this article, but, briefly, they refer to the automatic notification of faults that are in danger of not being cleared within a predetermined time from when first reported.

(*d*) *Field Engineer Work Lists* These parameters describe the identities and attributes of the field engineers controlled by the OU.

(*e*) *Sublist Identification* These parameters allow sublists for each group list to be specified. For each sublist declared, the system allows qualifying parameters to be inserted, chosen from one, more than one, or all of the available service-code/class-of-service combinations, exchange identities and fault localisaton codes.

(*f*) *Fault Clearance Commitment Times* These parameters describe the current lead times in working hours for up to eight classes of fault. These classes are synonymous with the fault localisation codes entered when test results are added to the FRR. The lead times may be amended by the S2. Values between 1 and 99 hours are acceptable for all classes and these values are used to calculate the clearance commitment time for the FRR.

Functional Splits

Although the RSCs can be described within the control parameters, an aditional degree of flexibility exists in terms of RSC organisation outside the SMSS. Because networking facilities are supported, it becomes possible to take a function and locate it separately if required. Thus a common, centralised reception unit could be implemented, with territorially-located test and distribution functions as separate OUs. The automatic routeing of new FRRs to the correct OU further enhances this aspect of system flexibility.

Once the organisational model has been described by the insertion of the control parameters detailed above, it becomes possible to load the database with customers' permanent information and to process fault reports.

RECORDS MAINTENANCE SUBSYSTEM (RMSS)

The records maintenance subsystem (RMSS) provides the necessary facilities for building and maintaining those files within the database relating to permanent information about customers' installations. Before the facilities provided by the RMSS are described, it is helpful to outline the record structures for permanent information on ARSCC/E, represented in Fig. 4.

(*a*) *Installation Header Record* Each public switched telephone network (PSTN) installation in the database has one installation header record in which are stored the name and address of the installation; the installation type, for example, private automatic exchange (PAX), direct exchange line (DEL), small business system (SBS); the

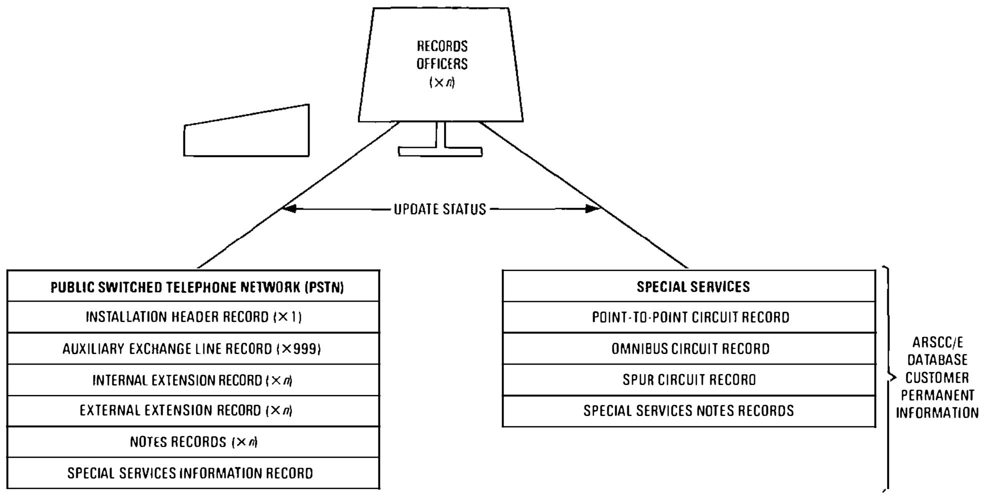

Fig. 4—Records maintenance subsystem

service code and class of service; the date of the installation and the directory number. In the case of a DEL, the circuit routeing details for the line are also included. Additionally, certain indicators may be present in the record, indicating that supplementary information in the form of plain-English freefield textual notes exists.

(*b*) *Auxiliary Line Record* For all PSTN installations other than DELs, there exists a record for each auxiliary exchange line associated with the installation. These auxiliary lines are the familiar PBX 'stroke numbers'. Included in the auxiliary line record is the full circuit routeing detail and a subset of indicators to indicate the presence of supplementary freefield notes text associated with the record.

(*c*) *Extension Record* For each PBX extension related to an installation, there can be one extension record, describing the extension and its location. If the extension is an external extension, then a supplementary record is also required containing the local and remote routeing details of the external extension. Once again, freefield notes can be associated with the extension record, these being highlighted by the use of notes indicators within the record.

(*d*) *Special Services Records* Many large PBX installations have special services circuits. ARSCC/E provides a special services information record, so that non-engineering customer descriptions of special services circuits can be related to the proper circuit designations. ARSCC/E is also able to maintain separate comprehensive special services records. These are subdivided into point-to-point and omnibus records. If the circuit is omnibus, then additional spur records are associated with it, one per spur. Because the data required to be retained for special services records varies greatly between circuits, much of the available space is dedicated to freefield textual notes, although encoded data such as the area code, fault reporting point and circuit maintenance control do exist.

Database Load Facility

By using the facilities provided within the RMSS, it is possible to manually enter the full details of any installation from scratch. This is, however, an arduous and expensive operation, which can be avoided by using mechanised data to be found in other systems within BT.

The customer rental record (CRR) system contains much of the information required for the ARSCC/E database, although not necessarily in a suitable format. In order to take advantage of this, data-extract programs have been written which process CRR records and recode the data into ARSCC/E formats. The CRR system can provide the name and address, the service code and class of service, the installation type and brief details of the equipment fitted (from the apparatus, facilities and services (AFS) codes used within the CRR system)). This data is extracted and transferred to ARSCC/E in the form of magnetic tape files, which are then subjected to the database load process.

The database load process is facilitated by a batch program contained within the ARSCC/E software set. It takes the data from CRR, one installation record at a time, and reprocesses it into the record formats required for ARSCC/E. It creates, within the ARSCC/E database, one installation record for each installation encountered on the tape file. During this process, it carries out many data integrity checks and reports on inconsistencies and duplications. Current versions of the database load program can load between 10 000 and 12 000 records per hour.

File Set Up Facilities

Once the database has been loaded, the remaining updating processes required to complete the ARSCC/E records are labour intensive. A team of trained VDU operators systematically work their way through the skeleton records provided by the database load, completing missing data and correcting errors, by reference to the RSC card records. Circuit routeing information is generally considered to be insufficiently accurate on RSC records, and therefore the file set up (FSU) team accesses more accurate records outside the RSC if required.

In order to facilitate the FSU process, features have been provided within the RMSS to access the database in record order, without the need to specify the circuit number of succeeding records, thereby much improving the productivity of the FSU team. This subset of facilities is granted at log-in time to those officers registered in the FSU function within the control parameters.

The FSU phase takes between three and six months, depending upon the resources committed and the size of the database. FSU operators can achieve as many as 300 record completions per day under favourable circumstances. During this time, the records themselves undergo amendment as a result of normal sales and engineering activity, and these amendments need to be reflected in the final database as well as the existing card file. This may be a function of the FSU team or the regular RSC maintenance personnel, who see it as an ideal opportunity to gain familiarity with the system before it is committed to live fault report traffic.

When the FSU phase is complete, the database is handed over to the regular maintenance personnel for normal records maintenance work.

Records Maintenance Facilities

ARSCC/E provides a comprehensive range of facilities for maintaining the database, which are allocated to records function officers, as identified within the control parameters, and are granted when the user logs in to the system under that function.

The general approach to records maintenance is menu driven, to match both the structure of the records and the methods required to modify them without errors and omissions. During each phase of updating a record, the system completes comprehensive data vets to ensure the integrity of the final data. This is particularly important in the case of large installations with hundreds of auxiliary lines and possibly thousands of extensions. To illustrate the concept, a simple example is described.

The task is to create a record for a PBX having many exchange lines and extensions. The records officer selects from the function's main menu the UPDATE INSTALLATION option. The system responds with a prompt for the installation number. If the installation exists on the database the installation header record is displayed, as a form, with the data fields unprotected. If the installation does not currently exist, a blank installation header form is displayed, awaiting entry of the required data. When each field on this form has been completed, the officer transmits the data to the system, which vets each field on the form for acceptability and consistency with other fields on the same form. Errors are highlighted and the form is redisplayed, together with a suitable prompt to correct the errors. Assuming no errors, the data is committed to the database and the function main menu is redisplayed. From this, the officer selects the UPDATE EXCHANGE LINE option and an exchange line update form is displayed. This sequence of menu selection, data entry, data vet and error correction is repeated for each exchange line and extension record required to complete the installation details. Should the officer omit any record type, the system informs the user and allows re-entry at the appropriate point to correct the omission.

The overall effectiveness of this approach means that the advice note backlog, a feature of most non-mechanised RSCs, becomes a thing of the past. Records become more accurate, more complete and more up-to-date; in turn, this leads to an overall improvement in the efficiency of the RSC.

(To be continued)

Managing for Quality

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UDC 65.018 : 658.81

This article is based on an address given by the author at several Local Centres of the Institution of British Telecommunications Engineers during 1985. The article highlights the importance of quality for satisfying customers' needs regarding delivery, performance and service. It analyses the methods, and their success, of quality assurance that have made the Japanese such formidable competitors in international trade. In conclusion, the author makes a number of observations for improving quality assurance in British companies, chiefly that quality should be seen less as a cost burden and more as an investment, and that it should apply to all business activities.

INTRODUCTION

Quality is concerned with satisfying customers' needs in terms of delivery, performance and price. It is every bit as relevant to a service industry as it is to a manufacturing industry, and it is not concerned only with bought-in goods. Nor is it a cost burden, but it is, on the contrary, a source of increased customer satisfaction, and hence increased business and increased job opportunities.

SATISFYING THE CUSTOMER

Throughout this article, the word *quality* is used to mean the 'totality of features and characteristics of a product or service that bear on its ability to satisfy a given need' (British Standard (BS) 4778 definition). Clearly, in order to be able to assure, control or improve quality, it is necessary to be able to evaluate it. This BS definition[1] calls for the identification of those characteristics and features bearing upon the 'fitness for purpose' of a product or service. The 'ability to satisfy a given need' includes price, availability, delivery, maintainability, reliability and all the other characteristics which the customer perceives to be important.

QUALITY COSTS

Quality costs can be considered under the headings:

- costs of prevention of failures,
- appraisal costs,
- failure costs in manufacture, and
- failure costs in use.

The essence of the modern quality-assurance approach (for example, BS 5750) is that effort spent on preventing failures is more than adequately paid for (perhaps many times over) in reduction of other costs and (perhaps more importantly) in increased customer satisfaction with the product or service, and hence in increased business.

Fig. 1 shows how, in a manufacturing situation, failure costs can be balanced against prevention and appraisal costs to strike an economic balance which reduces the sum total of quality costs. This is the balance which a manufacturer would seek in order to minimise the cost of his operations. Suppose, however, that this is put into a British Telecom (BT) context and consider, in addition to the manufacturing costs, the costs incurred by BT in terms of maintenance costs attending to failed devices (let alone lost revenue costs), then the picture looks rather different (see Fig. 2). Fig. 2 shows that, when the totality of costs (all of which are eventually borne by the customer) is considered, the optimal balance for minimum overall costs is far to the right (that is, towards higher quality) than that in Fig. 1. This will be referred to again in the context of the Japanese experience.

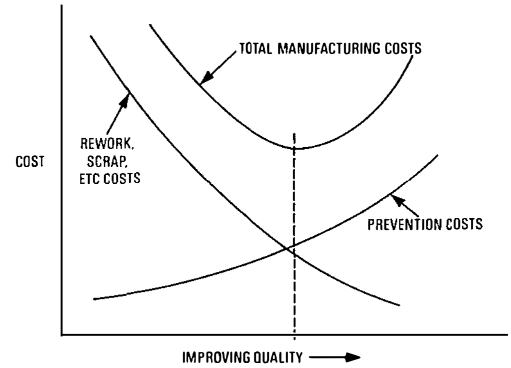

Fig. 1—Balance of prevention and appraisal costs in a manufacturing situation

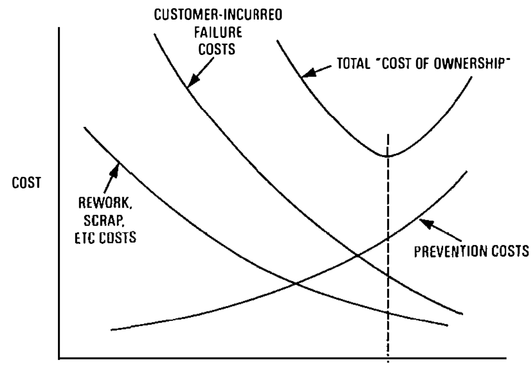

Fig. 2—As Fig. 1 but also taking account of customer-incurred failure costs

QUALITY ASSURANCE

It has for some time now been recognised in manufacturing industry that, in order to achieve consistently satisfactory quality levels in output, it is insufficient to specify the parameters of the product being produced as, in such circum-

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stances, failure of the product to satisfy the specification requirements is likely to result in high wastage costs or rework (or even redesign) costs. A better approach is to seek assurance of quality by specifying the requirements of the total system within which the product is manufactured. BS 5750 defines the requirements of such a quality-assurance system.

INVESTING FOR QUALITY

It will be seen from Fig. 2 that BS 5750 will be likely to incur higher prevention costs (that is, the costs of establishing and maintaining the quality-assurance system), but that these costs are more than paid for in reduced appraisal and failure costs. This leads to the thought that the improvement of quality can usefully be considered as an investment opportunity with huge returns because a comparatively small effort in the establishment of sound quality-assurance systems can bring enormous savings in the penalty costs of inadequate quality. Experiences in the USA[2] indicate that returns on investment of many hundreds of percent per annum is the rule, not the exception, for quality-improvement projects.

An important feature of the BS 5750 quality-assurance specification is the need for a 'feedback loop' so that departures from acceptable standards in terms of scrap levels, rework levels, or other non-conformance to defined requirements are detected, and appropriate corrective action initiated. It is important to note that the customer is not within this loop and that any corrective action required is taken before the goods or services are provided to the customer (see Figs. 3 and 4).

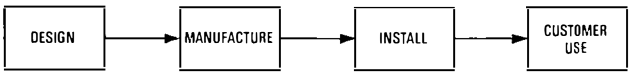

Fig. 3—'Open-ended' supply system

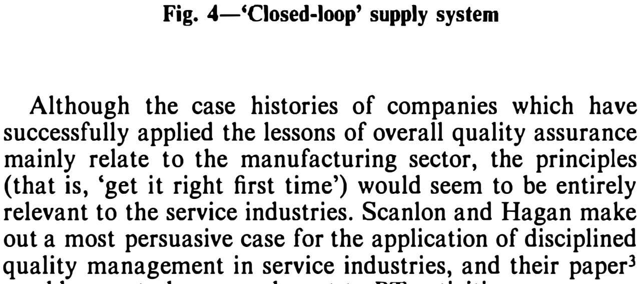

Fig. 4—'Closed-loop' supply system

Although the case histories of companies which have successfully applied the lessons of overall quality assurance mainly relate to the manufacturing sector, the principles (that is, 'get it right first time') would seem to be entirely relevant to the service industries. Scanlon and Hagan make out a most persuasive case for the application of disciplined quality management in service industries, and their paper[3] would seem to be very relevant to BT activities.

THE JAPANESE EXPERIENCE

That the distribution of world trade in manufacturing has, over the last couple of decades, moved markedly in favour of Japan at the expense of (partly) the USA, but mainly the UK, is beyond question. Clearly, it would be an over-simplification to suggest that this is due entirely to the factor of quality. These are many explanations offered for the shifts in the balance of world trade, but it does not escape notice that Japan, which puts a very high premium on quality, has consistently outpaced other nations for over 20 years now. There can be little doubt that superior quality is a major reason for the dramatic shift in market share to Japan of, for example, television receivers, video-cassette recorders, hi-fi equipment, cars and motor cycles.

Before (say) the late-1960s, Japan was not noted for the quality of its goods but, after about this time, Japanese and Western quality standards can be seen, in retrospect, to have diverged.

Three major characteristics of Japan's approach to quality improvement can be identified:

(*a*) top-level leadership of quality drives (unlike the West where quality is still largely regarded as a specialist function),

(*b*) massive quality-related training programmes involving workers and managers at all levels, and

(*c*) annual programmes (with targets) for quality improvement.

The Japanese approach can be summed up as follows:

(*a*) High quality and high reliability are seen as principal factors in gaining and retaining market advantage.

(*b*) Effort expended on quality and reliability is not regarded as a negative charge on the profits but rather the opposite; that is, 'How much extra turnover and profit will be generated by greater customer satisfaction and by reduced scrap, rework, warranty costs, etc?'

(*c*) Quality and reliability systems are thorough and not only are concerned with manufacture, but start at the design stage with exhaustive design approval testing and reliability testing (Get it right first time!).

An interesting, and perhaps significant, observation of a difference between the Japanese and Western production methods[4] is that the Japanese tend to have little interest in Western notions of trade-offs between quality and cost. In other words, maximum rather than some predetermined optimal quality attainment is the goal.

If a single distinctive feature of the Japanese approach to quality is to be distilled from the many observations and studies which have been made by Western visitors to Japan, it is that quality is a total company activity—indeed, a total company objective—running through design, development, purchasing, manufacture, installation and maintenance, and is most certainly not an 'add-on' feature of manufacture.

QUALITY MEASUREMENT AND CONTROL

Clearly, before quality can be improved, it must be defined and measured. There may be no better definition than the one already quoted under 'Satisfying the Customer'. Fault reports per station per annum is perhaps an obvious quality measure which is already recorded in BT's service statistics system (TIP1) but, for it to be of help in improving quality levels, two conditions are necessary. Firstly, the faults need to be analysed into causes (instrument faults, drop-wire faults, cable faults, exchange faults, etc.) and, secondly, feedback loops need to be established to ensure that corrective action is taken at the appropriate points. It would also perhaps be better if means could be devised to detect departures from a normal state in time for corrective action to be taken before a customer complains. The experience of Pedigree Petfoods[5], although perhaps not of obvious relevance to BT, is worth mentioning here. In this company a small team of quality specialists uses statistical sampling techniques to monitor the company's manufacturing and production operations. Small departures from the norm thus give advance notice of major problems in time to head them off.

On the subject of quality measurement, it is important not to lose sight of the cardinal objective: to satisfy the customer. It is with this objective in mind that major telecommunications operators have found it useful to employ outside agencies to survey, on a regular basis, customers' attitudes to the quality of service provided. In the BT Telcare system, the company's main activities of provision, repair, transmission, billing, operator services, and international and private services are monitored in this way. This system provides useful feedback for the development of quality aims.

QUALITY-IMPROVEMENT PROGRAMMES

To improve quality, what are needed are quantified quality aims and objectives to be achieved in a given time-scale or, in short, quality-improvement programmes (QUIPS). Attention has already been drawn to these in the context of the Japanese experience. However, if it is difficult to think of Japan other than as a far-away place of which little is known and whose customs and practices cannot be translated here, many examples of the successful application of quality-improvement programmes in the UK can be found.

The best documented cases[6] are to be found in the defence, aerospace and nuclear-fuels sectors of industry. In each of these sectors, there is no question of a trade-off between cost and quality. Quality must be the highest which technology can attain, as the penalty costs of inadequate quality are, of course, unthinkable.

Common features to the quality-improvement methods of those companies which have been seen to be successful are:

(*a*) the recognition that quality (and reliability) cannot be 'inspected into' a product but must be designed in at all stages of production (design, development, manufacture, installation, etc.);

(*b*) the setting of quality- and reliability-improvement targets;

(*c*) the use of statistical monitoring techniques by quality specialists but placing responsibility for corrective action with line management;

(*d*) the establishment of 'closed loop' feedback systems to signal impending departures from standards, and

(*e*) attention to 'whole life' quality and reliability.

THE ENGINEERING DIMENSION

The need for disciplined systems and procedures for the improvement of quality in business activities offers a significant opportunity for the application of what Sir Monty Finniston[7] called the 'the engineering dimension' to business. Engineers are particularly qualified to make a contribution because:

(*a*) an engineer is first and foremost an innovator whose business is the bringing about of change;

(*b*) an engineer is numerate, trading in measurement and analysis;

(*c*) an engineer is familiar with the use of 'feedback loops', which are an essential part of any quality-improvement mechanism; and

(*d*) an engineer is entirely 'at home' with the balancing of costs and benefits of investment appraisal.

Engineers, therefore, have as much to offer as anyone in the organisation and management of the changes necessary to bring about the much needed improvement in the quality of business operations.

STRATEGY

The point has been made that the essential first step in improving quality is to have top-level commitment and leadership. Without this, all the scurrying of quality specialists will be to no avail.

Next, it is necessary to let everyone know, all the way down the line, that the business is committed to the improvement of quality. A most useful vehicle for broadcasting management's quality policy is a quality manual. This manual would explain management's policy, and needs, therefore, to be written by management in plain language. It should not be a technical document produced by specialists, although professional help can be invaluable in its drafting.

Given the statement of policy aims, it is then necessary to define and quantify specific quality-improvement aims and to set up the necessary measurement and feedback facilities so that departures from standards can be analysed into their causes, and corrective action taken.

The size of the educational task is therefore considerable not only in explaining what quality is and why it is good for business, but also (and this is likely to be much more difficult) in the generation of a quality-conscious 'culture' such as the Japanese now have.

SETTING THE TARGETS

All too often, improvement targets (for example, for quality, efficiency, productivity, etc.) are set on the basis of a modest year-on-year improvement (for example, 3% per annum) without regard to the absolute scope for improvement. In the case of quality improvement, a better approach is to recognise the gap between achieved performance and possible performance and to acknowledge this as a quality cost. Only in this way can the burden of inadequate quality be fully recognised.

CHOOSING WHERE TO START

Clearly, it is not possible to tackle all of the quality problems simultaneously and a method is needed to assist in the choice of priorities. Such a method is available in the form of Pareto analysis, or consideration of 'the vital few' and 'the trivial many'. In the case of TIP1, for example, close examination of the causes of complaints is bound to lead to the conclusion that a large proportion of the complaints is due to a small number of causes (the vital few) and, conversely, that a relatively small proportion of the complaints is due to a large number of causes (the trivial many). It is to these vital few that attention must be paid if a major impact on reducing causes of complaints is to be made.

MOTIVATION

As the Prime Minister said in launching the National Quality Campaign in 1983, 'everyone involved in industry must recognise that quality is their business'. It is important, therefore, that all staff at all levels are trained, equipped and, above all, motivated to achieve high quality. This will come primarily from a management team committed, at all levels, to the pursuit of quality resulting in the development of a quality ethos throughout the organisation.

Recent experience in the USA has shown the benefits of the use of team bonus award schemes in the fostering of the team spirit which is so essential to the success of any enterprise. One large and successful telecommunications operating company in the USA, for example, operates a group bonus scheme which is related both to financial performance and to customer satisfaction as measured by a system comparable to BT's Telcare system.

BT QUALITY ASSURANCE

The observations in this article are based upon experiences gained by BT's Quality Assurance Division, which has been at the forefront of the development of quality-assurance systems for many years now and which has been responsible for persuading and assisting BT's suppliers to implement comprehensive quality-assurance systems in accordance with BS 5750. The work of BT's Quality Assurance Division is now little concerned with 'test and inspection', but primarily concerned with total quality systems. These experiences would seem to have as much relevance to BT's internal operations as they do to those of its suppliers.

SUMMARY

This article has drawn upon observations made from manufacturing industry both in the UK and in Japan to make the following points:

(*a*) Quality is not a cost burden but is, on the contrary, a profit generator.

(*b*) There is an imperative need, and enormous scope, for improvement in the quality of UK goods and services.

(*c*) Responsibility for quality rests squarely with line management and particularly with senior management.

(*d*) Quality is every bit as relevant to a service industry as it is to a manufacturing industry.

(*e*) There is a need for a major shift in attitudes to quality away from the belief that there is a 'good enough' quality level.

(*f*) Quality applies to all business activities and not only to the manufacture of goods.

(*g*) Improvement can be achieved only by the establishment of quality-improvement programmes with quantified quality objectives.

(*h*) It is not sufficient to measure quality achievement. Feedback loops need to be established to ensure that appropriate corrective action is taken when achievement is below standard.

(*i*) Particular attention needs to be paid to customers' perception of quality.

(*j*) There is, in BT, in-house expertise in quality-assurance methods which is being applied, with advantage, to BT's own internal operations.

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Biography

Tom Lomas is a Deputy Director in BT Development and Procurement. He joined BT in 1947 as a Youth-in-Training in the Liverpool Telephone Area. Shortly after National Service with the Royal Signals and a spell as Technical Officer on transmission work in Liverpool, he was appointed Assistant Engineer in the Engineer-in-Chief's Office, where he was engaged upon the development, installation and maintenance of submarine cable systems. After promotion to Executive Engineer in Local Lines Branch in 1958, he worked in the team which introduced transistor-based transmission systems into the local line network. During this time, he studied at evening classes for the Diploma in Electrical Engineering, qualifying in 1961. From 1965–69, he was a Senior Executive Engineer in Telecommunications Headquarters, where he was engaged successively on work study and operational research work. In 1969, he was promoted to Assistant Staff Engineer in the Management Sciences Division, where he pioneered the use of mathematical models in investment decision making in BT. He was appointed joint Head of the Management Sciences Division in 1975. In 1977, he was appointed Assistant Controller of Contracts and, two months later, Deputy Controller of Contracts in what is now the Procurement Executive (PE). On the reorganisation of PE in 1979, he was appointed Head of Professional Services in Materials Department, and, in 1981, he was promoted to his present position with responsibility for cost analysis, quality assurance and the Materials and Components Centre.

International Switching Symposium, 1987

The International Switching Symposium (ISS) is held once every three years at various locations throughout the world. It is a major switching event that brings together both leading experts in this field of study and representatives from various operating companies.

The Symposium embraces all aspects concerned with switching systems from their conception, through design to field experience. Considerable attention has been focused recently on computer-controlled switching systems, but ISS 87 will look ahead to the twenty-first century and will concentrate on the technologies that appear to be keys to the future.

ISS 87 will be held from 15–21 March 1987 in Phoenix, Arizona, USA. Papers in the following broad areas of interest are invited for consideration by the ISS Technical Committee:

Advanced switching concepts
Network architecture innovations
Operating experiences
Computerised operations systems
Forward-looking principles and architecture
Impact of new service needs on switching
Reliability and quality
Novel hardware technology
Advances in software development

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Telephone Poles in the British Telecom Network—A Review

Part 2—The Wood Pole as an Engineering Structure

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This three-part article reviews the subject of telephone poles. Part 1 dealt with the wood pole in terms of timber technology. This part deals with the wood pole as an engineering structure. It begins by examining the engineering factors that must be taken into account to produce a safe structure. Particularly important is the need for regular examination and testing of wood poles, and this is given particular attention. Part 3 will go on to review the use of alternative materials for telephone poles, with particular emphasis on the newer hollow pole.

INTRODUCTION

The first part* of this article discussed the timber technology of wood poles. It is now necessary to examine the wood pole as an engineering structure capable of resisting imposed loads—wire and cable tensions, wind and ice loadings, and forces resulting from staff working aloft. To produce a safe structure, it is necessary to obtain information on the magnitude of applied loads and the strength characteristics of the pole. The likelihood of decay has an especially important influence on the safety of staff working on a wood pole, and well-established testing procedures have been in operation for many years to ensure that gross decay, which may seriously weaken a pole, is detected.

STRUCTURAL ADEQUACY

Poles are used in a wide diversity of circumstances and it would not be appropriate to expect each installation to be subjected to a separate structural analysis. As a result, general rules have been formulated to cover nearly all circumstances. These rules have been developed by using quite basic structural formulae; more sophisticated approaches would not be likely to add to the quality of the analysis because of the many uncertainties in the knowledge of both strength and loading. Provided reliable data, preferably in a statistical form, is available on the range of situations likely to be encountered, then a rational basis for design can be established.

Strength

The wood pole, being a lightly-processed material, poses a much more difficult problem of strength description than materials which are either 'man-made', or natural materials which are more heavily processed and selected. With materials such as steel and concrete, small representative samples can be taken and tested to give a good indication of the properties of the total batch of material, but this is not possible for wood poles as sample test pieces cannot be assumed to be representative.

The calculated strength of a pole is subject to several important variables:

(*a*) The strength of the timber varies across the cross-section.

(*b*) The cross-sectional diameters and rate of taper of a pole can vary within quite wide limits, while still being within specification. In addition, the cross-section may be only approximately circular and could show marked irregularity.

(*c*) The presence of knots, shakes, twists and other defects can influence strength.

(*d*) The degree of fixity of the base of the pole is not well defined because of the nature of the ground conditions. The stiffness of the foundation affects the effective length of the pole in both bending and compression.

(*e*) Some decay may be present in an older pole, either at the surface or internally, and must be allowed for in making assumptions about strength.

Because of such variations and the lack of effective non-destructive testing techniques, the only satisfactory way of gaining useful data is to undertake destructive tests on batches of poles to the same nominal specification. The batches for testing need to be sufficiently large to enable a valid statistical description of strength to be obtained; a batch sample of 40 poles or more to the same nominal specification is preferred, although not often practical. Fig. 15 shows a pole being subjected to a test to destruction—note the large deflection before failure ensues.

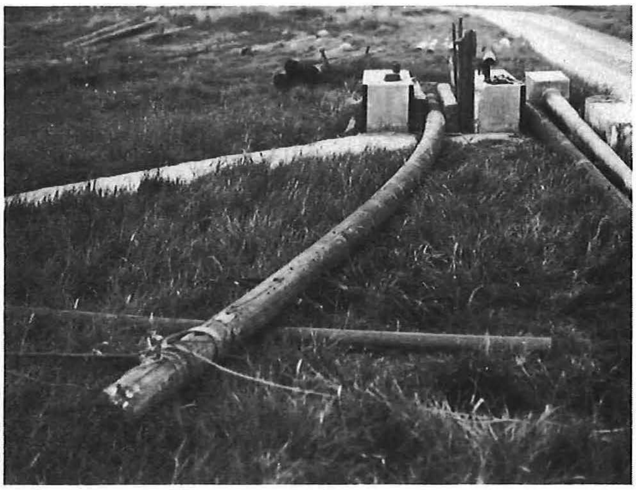

Fig. 15—Pole under test

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TABLE 2
Results of Tests to Destruction on Scots Pine/Redwood Poles

Size	Date of Test	Number in Sample	BS 1990 Average Ultimate Load (kN)	Ultimate Load (kN)		Height of Break above Ground (m)	
				Mean	Standard Deviation	Mean	Standard Deviation
7 m Light			4·31				
	1979	40		5·49	1·19	1·0	0·7
8 m Light			4·40				
	1977	20		7·02	1·01	0·9	0·6
	1979	40		5·10	0·99	0·7	0·7
9 m Light			4·46				
	1977	20		6·40	0·96	0·9	0·8
	1979	40		5·16	1·02	1·2	0·9

The relevant British Standard[13] tabulates pole strengths on the basis of an ultimate extreme fibre stress of 53·8 N/mm² for Scots pine/redwood. For convenience, this is the value used for routine pole-strength calculations in British Telecom (BT) in conjunction with a factor of safety of 4. The margin of strength is then sufficiently high so that the inherent variability of pole strength is adequately catered for. For some purposes, it is, nevertheless, necessary to have a measure of the scatter of strengths about the mean. Such data is needed when comparisons are made of the performance of batches of poles of different species or from different sources, or when probabilistic assessments of pole safety are carried out.

When the results of destructive tests on poles are interpreted, there are uncertainties in calculating the extreme fibre stress at the point of failure because of dimensional and other variables, and it is more meaningful to use ultimate load rather than ultimate stress values as the basis for comparison. Table 2 summarises the results of two recent series of tests carried out by BT. The 1977 tests were on normal quality Scots pine, but the 1979 tests were on poorer quality material. It will be noted that the standard deviation is large, even for the good quality poles, and this is typical of all results from testing poles. Poles from a number of different sources, and of different species, generally yield standard deviations in the range of some 10 to 20% of the mean strength. The wide variation in the position of the point of fracture illustrates another of the problems of attempting to work on an ultimate stress basis rather than ultimate load as poles do not break necessarily near the point of theoretical maximum stress.

Figs. 16(*a*) and (*b*) are histograms of results of the tests on the 8 m light (L) poles of Table 2.

Loading

The loading on a pole comes from four possible sources:

(*a*) loads applied by wires and cables, comprising the initial stringing tension plus any increase in tension due to wind and ice;

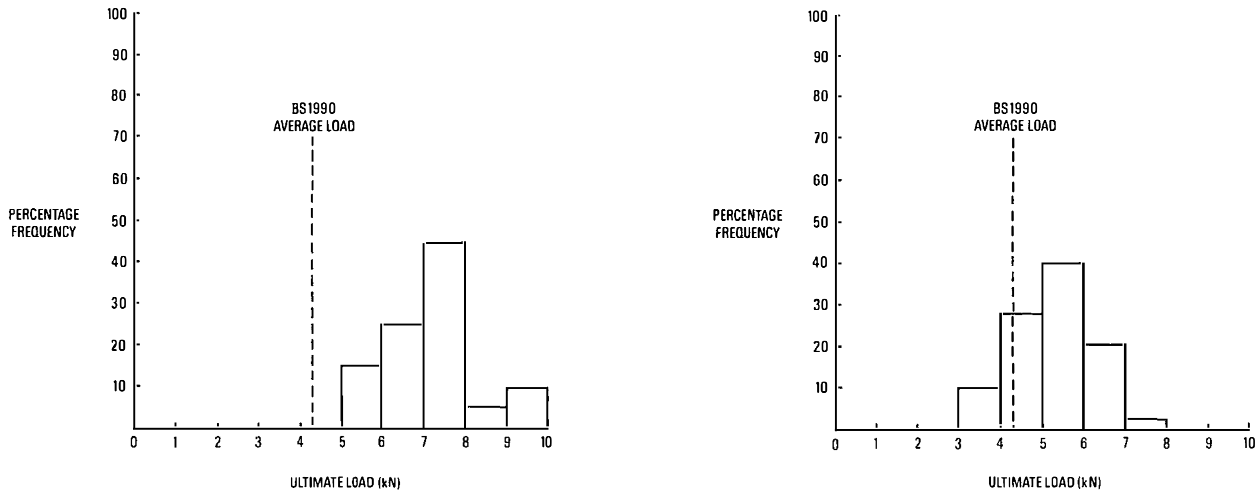
(*b*) wind and ice loading on the pole itself;

(*c*) forces applied by staff during normal climbing or working aloft; and

(*d*) suddenly-applied forces should a person fall off a pole and be arrested by their safety belt.

Factor of Safety

A factor of safety is a means used to guard against uncer-



(*a*) Ultimate load capacity of sound poles

(*b*) Ultimate load capacity of brash poles

Fig. 16—Ultimate load capacity

tainty in the knowledge of the strength and loading of an engineering structure[14]. It is defined here as:

$$\frac{\text{load to cause failure of pole}}{\text{maximum design loading}}$$

A high value of factor of safety of 4 has been used successfully for pole installations for many years. In calculating the design strength, the pole is assumed to have the minimum specified dimensions with a wind of 32·8 m/s (80 mile/h) blowing on the wires/cables and pole in the direction which would give rise to the worst loading conditions.

Recently, experimental work has been undertaken by BT to check that the dynamic load applied by a falling person arrested by the safety belt would not cause an already heavily-loaded pole to break. It was found that the peak load on the pole was 2·4 times that of the force applied by a person leaning back normally in the safety belt. By using this peak load in conjunction with a pessimistic view of several other factors, such as a decayed and undersized pole with markedly asymmetric cable loading, it was found that the effective safety factor still did not fall below 2·4. It is of course assumed that staff would not be working aloft in extreme weather conditions.

Pole Foundations

The depth at which a pole is set in the ground is determined by circumstances. Table 3 gives recommended values.

TABLE 3
Pole Foundation Depths

(*i*)	Average conditions	Poles up to 15 m long, 1·2–1·8 m deep Poles over 15 m long, up to 2·4 m deep
(*ii*)	Unstayed distribution poles	300–600 mm deeper than above figures
(*iii*)	Made ground. Loose soil. Poles in banks.	Increased depth to be allowed according to circumstances
(*iv*)	In rock or very hard ground requiring blasting	300 mm less depth than (*i*) or (*ii*) above

The most effective excavation for a pole is that which creates the minimum amount of disturbance to the surrounding soil, and the 255 mm diameter cylindrical hole drilled by the auger of the pole erection unit meets this requirement. When holes are dug manually, it is possible to produce similar but slightly tapering holes by using a digging bar and 'spoon'. A small slot is cut on one side of the hole to facilitate manual erection of the pole; for large poles, a deep slot is required. In all cases, such slots must be cut at right angles to the principal pull on the pole so that the heaviest pressures exerted by the pole bear against undisturbed earth. It is very important to ensure that all soil replaced in the hole around the pole is thoroughly compacted to ensure long-term pole stability.

Staying

Stays are used

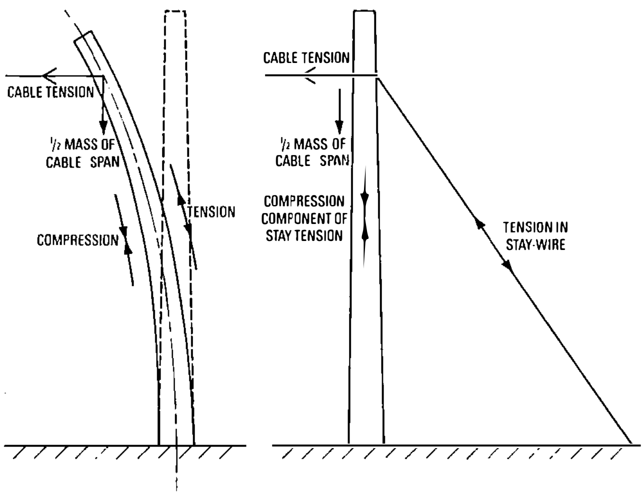
(*a*) to increase the load-carrying capacity of a pole by relieving the pole of bending stresses,

(*b*) to limit the progressive collapse of an overhead route should a failure take place at one section,

(*c*) to reduce wind-induced movement of the poles which might otherwise lead to fatigue failure of cables or wires, and

(*d*) to stabilise a pole against long-term creep in the direction of the applied load. If the load is high, the wood pole itself would tend to take up a permanent set or the soil could yield, causing the pole to lean.

Staying is a very efficient way of utilising the inherent strength of a pole. This can be illustrated by comparing the forces on, say, the terminal pole on an aerial cable route. Fig. 17(*a*) shows that, if the pole was not stayed, the cable tension can be resisted only by the bending moment and shear forces within the pole, as the pole functions as a cantilever. However, if a stay is fitted to the pole at the point where the cable is terminated (Fig. 17(*b*)), then the pole is transformed into a strut. The cable tension is reacted by the



(*a*) Forces on unstayed pole (*b*) Forces on stayed pole

Fig. 17—Forces on terminal poles on aerial cable route

horizontal component of the stay tension, and the vertical reaction of the stay tension imposes a compressive force in the pole. The amount of bending of the pole is negligible and the failure mode would then be buckling under the compressive load. Comparison of the safe loads for unstayed and stayed poles will show that the addition of a stay greatly increases the cable tension which can be applied to a pole; for example, the failure load on an unstayed 9 m medium pole is 8·15 kN, but the addition of a stay at an angle of 45° to the ground increases the failure load to 70·4 kN: staying in this case improves the load-carrying capacity by a factor of 8·6. The ratio of strength between the stayed and unstayed pole reduces with increasing height. The reason for this is that the bending moment increases linearly with height but the buckling load reduces in proportion to the square of height; nevertheless, the ratio of strengths is still as high as 4·8 for the largest of the standard range of medium poles.

As the magnitude of the actual buckling load depends significantly on the degree of initial straightness of the pole, there is benefit to be gained from selecting the straightest poles for use in those circumstances where the compressive forces will be highest.

A single stay suffices in most circumstances, but two or

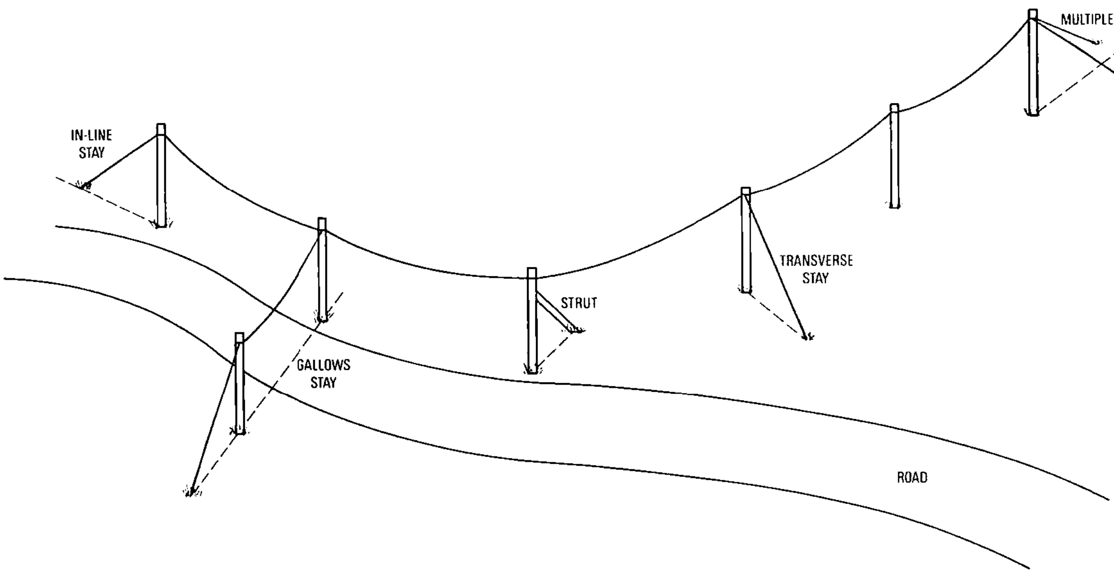


Fig. 18—Varieties of staying

more may be fitted to a heavily-loaded pole, provided the pole can withstand the high compressive stresses which result.

The following lists the circumstances where stays can be fitted (Fig. 18):

(*a*) They can be fitted in-line with the route to resist the wire/cable tension. This tension comprises the initial setting-up tension, which would be increased by the imposition of ice or wind loading.

(*b*) They can be fitted transverse to the route to resist wind loading on the route and pole. Such stays are also used to resist the transverse component of wire/cable tension at a change of direction in the line of the route.

(*c*) They can be fitted as 'flying stays' (gallow stays) when there is insufficient space by the pole to fit a transverse stay. A typical location would be on a bend in a road where it is not possible to fit a stay on the road side of the route pole; a stay is then carried over the road at a high level to another pole on the other side of the road. This latter polc can then be stayed normally.

As stays contribute greatly to the stability of an overhead route, it follows that stays need to be well maintained—fully tensioned, and free from corrosion or damage—or the route will be susceptible to failure in severe weather conditions.

Struts

A strut is made from a suitable pole, and acts as a prop for the route pole (Fig. 19). It is designed primarily to take a compressive load and so would be used on the inside of the angle at the change of direction of a route in a location where it is not possible to fit a stay on the outside of the angle. Stayblocks are bolted near the foot of both the route pole and the strut to improve stability by resisting any tendency of either to lift out of the ground in severe loading conditions. Strutting is more costly to install than staying, and its use is therefore minimised.

Blocked Poles

Situations may be encountered where extra stability must be provided but neither stays nor struts can be fitted; in such circumstances, blocking can be used. Wood blocks are bolted to the buried portion of the pole (Fig. 20(*a*)), thus providing a more stable foundation. Blocking is also used in poor

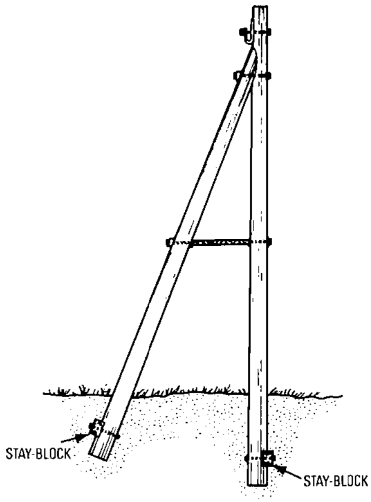


Fig. 19—Strutted pole

ground, even where stays are fitted, to prevent the pole from sinking into the ground. Where blocking is used, the pole itself must be of sufficient strength to withstand all bending stresses.

In extremely poor soils, a variation of blocking can be used: a short pole is buried in the ground with stays connecting the route pole to the ends of the buried pole (Fig. 20(*b*)).

Stay-Wire

The requirements for a stay-wire are as follows:

(*a*) It must have a small extension under load with minimal non-elastic stretch, otherwise stays would become slack after experiencing high loadings.

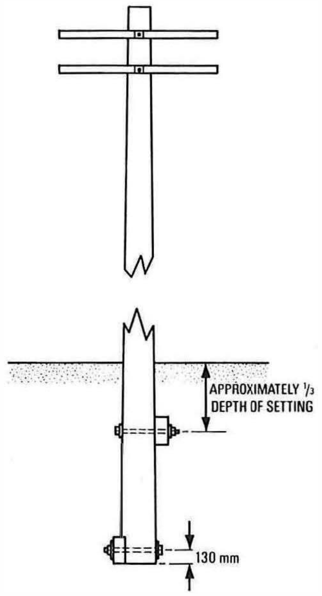
(*b*) It must be sufficiently flexible for handling.

(*c*) It must have good corrosion resistance.

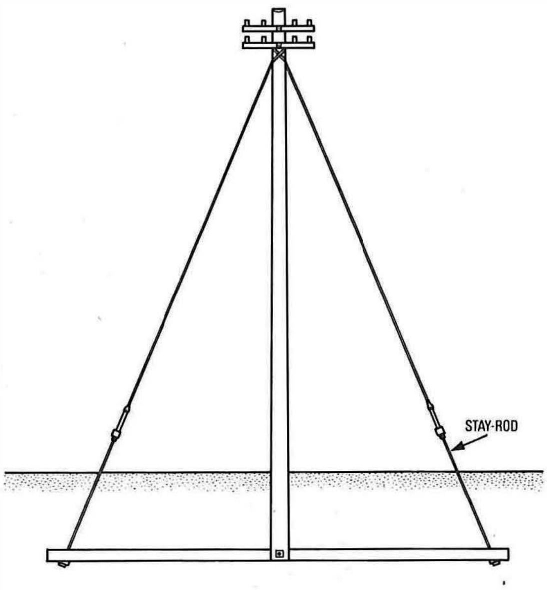
(*d*) It must be capable of being readily terminated at the pole attachment and on the stay anchorage.

(*e*) It must be strong enough to cater for all staying situations.

These requirements are satisfied by 7-strand steel wire, and two sizes are used, known as *Wire, Steel 7/2·65* and

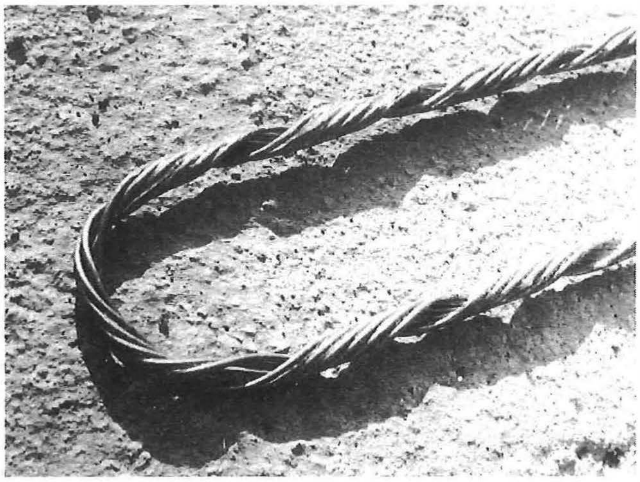


(*a*) Blocked pole



(*b*) Buried pole used for blocking

Fig. 20—Blocking



(*a*) Preformed helical stay-grip

(*b*) Stay-grip terminating a stay-wire on a screw-type stay-anchor

Fig. 21—Stay grip

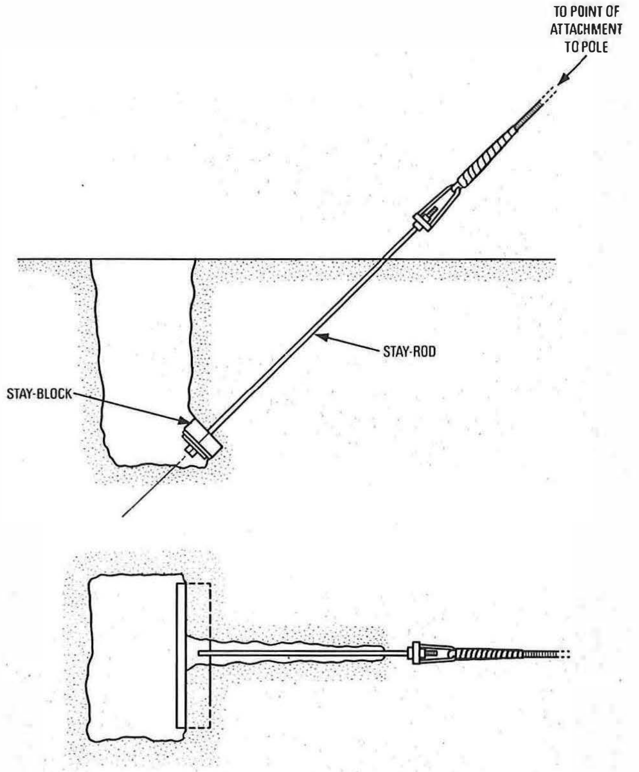
7/2·00. These stay-wires comprise seven strands of medium tensile steel wire which has a hot-dipped galvanised coating.

Formerly, the method of terminating a stay-wire was to use a hand-made splice on a lower-tensile 4- or 7-strand wire, but a much simpler method was introduced when poling work was mechanised. This termination uses a preformed helical grip which is wound on to the stay-wire and which locks itself tightly into place when the wire is under tension (see Figs. 21(*a*) and (*b*)). A coating of aluminium oxide on the grip improves its efficiency.

Stay Anchorages

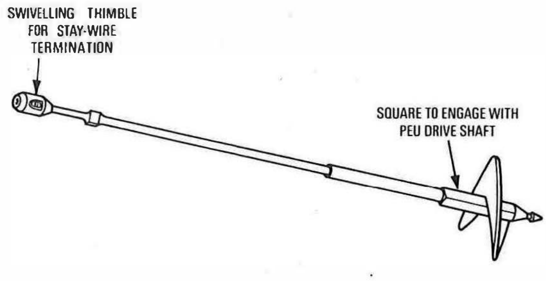
Before the advent of mechanised pole erection, the standard method of providing a ground anchorage for stays was to use a buried wood stay-block. The connection between the block and the stay-wire was by means of a stay-rod (Fig. 22), which also provided an adjustment facility to permit tensioning of the stay-wire. The essential feature of this type of anchorage was to excavate the hole so that the block would bear against undisturbed soil.

Two types of anchorage are currently used. One is a screw-type stay anchor (Fig. 23), which can be screwed mechanically into the ground by the pole erection unit. By screwing the anchor into the ground the soil is subjected to minimum disturbance, and a cone of soil is mobilised to resist the stay tension. The other design of anchor is used where machine installation is not possible. The anchor shaft



Note: Excavation prior to backfilling

Fig. 22—Use of wood stay-block with stay-rod



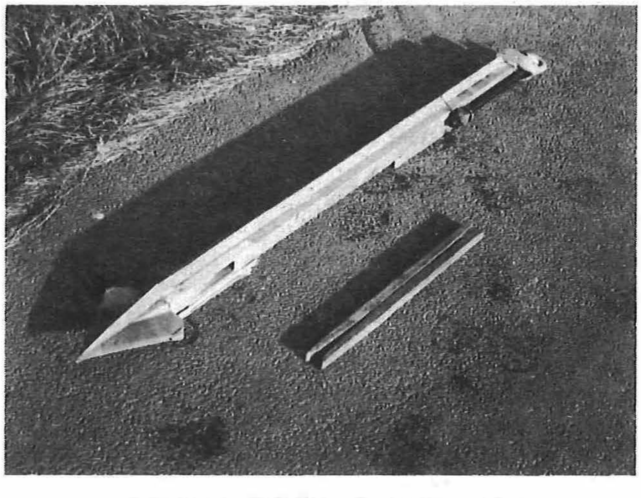
PEU: Pole erection unit

Fig. 23—Screw-type stay anchor

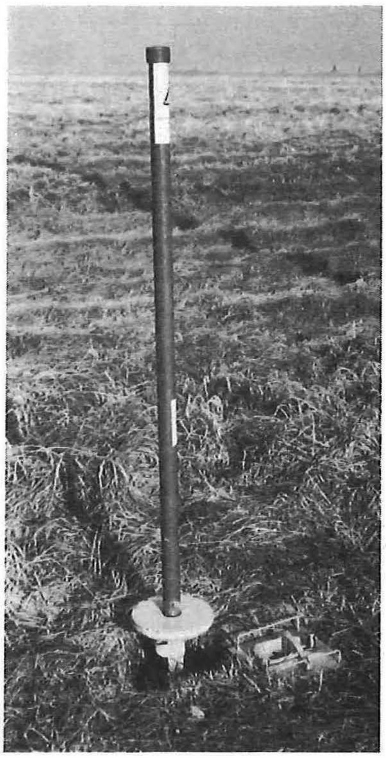
is shown in Fig. 24(*a*) in the condition in which it is driven into the ground with a slide hammer until the required depth is achieved. At this stage, the fluke set (Fig. 24(*b*)) is dropped down the anchor shaft, and the slide hammer is used to drive the fluke set against a wedge in the bottom end of the tube, which forces the flukes outwards through apertures in the shaft into the ground. Fig. 24(*c*) shows the final position of the flukes.

POLE ERECTION

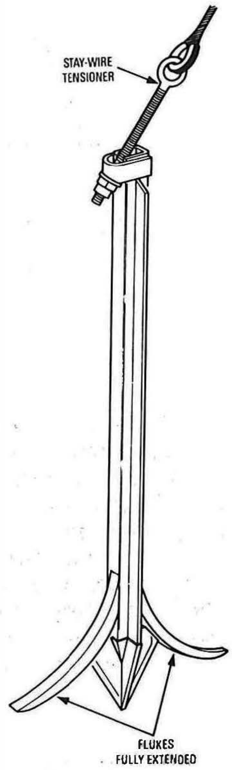
A major improvement in manpower productivity in external work resulted from the mechanisation of poling in the 1960s. Previously, sizes of working parties varied according to pole size, and ranged from three to 10 or more for erecting poles manually. Mechanical aids had been limited to the use of derrick poles and blocks and tackle. Even with such limited resources, there were many instances of heavy poles being manhandled over the roofs of buildings to reach sites which were otherwise inaccessible. Vehicle-mounted cranes were used from time-to-time, but the major improvement in efficiency had to await the introduction of the pole erection unit in the late-1960s[15]. The pole erection unit was introduced as a result of experience of a trial of a number of line construction units based on North American practice in the



(*a*) As supplied, fluke shown separately



(*b*) Insulated slide hammer, anchor driven fully home



(*c*) Position of flukes after driving

Fig. 24—Anchor Stay Manual No. 1

early-1960s[16]. Nowadays, some 60% of all poling work is undertaken by pole erection units operated by two-man parties. Most of the remaining poles are erected manually, usually where the site cannot be reached by a vehicle; fortunately, present-day poling work is restricted to light and medium poles and most manual erection is within the capability of a four- or five-man working party. Some poling work is also undertaken by an open-platform vehicle equipped with a hydraulically-powered crane.

The pole erection unit can carry up to nine poles and provides a range of mechanised facilities powered by a hydraulic pump driven from a power take-off from the vehicle's engine. The corner-mounted rotatable boom can act as a crane for lifting and placing the pole in position (Fig. 25(*a*)); it carries a hydraulic motor for driving an auger for drilling the foundation hole (Fig. 25(*b*)), and for driving screw-type stay anchors into the ground.

Additional facilities include a hydraulic jack for freeing poles prior to recovery. Power tools such as road breakers, and tampers for consolidating backfilled soil are also part of the standard equipment. The latest type of pole erection unit also has the facility for fitting a personnel bucket to the boom to facilitate work at the top of the pole.

The full efficiency of such a unit is often constrained by the need to excavate a pilot hole carefully by hand before boring in order to avoid buried utility plant. Another constraint is that poling work is commonly spread thinly over a wide geographical area and careful programming of the workload for the pole erection unit is essential if the relatively expensive vehicle is to be economically employed.

(*a*) Placing pole in position

(*b*) Augering pole hole

Fig. 25—Pole erection unit

CALCULATIONS OF POLE STRENGTH

The preceding sections on strength and loading have drawn attention to the difficulties arising from the inherent variability of wood, but for the day-to-day design of pole installations, assumptions are made to simplify structural analysis. The adoption of a high safety factor permits the following assumptions to be employed:

(*a*) The properties of the wood in the pole are assumed to be uniform and the wood is taken to be a homogeneous, isotropic and perfectly elastic material.

(*b*) Calculations are based on the following properties for Scots pine/redwood in British Standard BS 1990:

Ultimate extreme fibre stress: 53·8 N/mm^2
Modulus of elasticity, E: 10 480 N/mm^2

Both larch and Douglas fir are stronger, and so the above figures suffice for poles of these species.

Bending Case (Unstayed Pole)

The unstayed pole acts as a cantilever (Fig. 17(*a*)). The strengths given in BS 1990 are calculated strengths with the assumption that simple bending theory applies and that the pole is supported rigidly by the ground. BT utilises a factor of 4 on the ultimate loads given in the British Standard for design purposes. Table 4 shows the allowable loads for the standard sizes of pole used in BT. These loads are based on the strength at the critical cross-section of the pole, which occurs either at the ground line or at a point where the diameter is equal to 1½ times the diameter at the point of application of the load, if this point is above ground level (see Appendix 1 for derivation).

TABLE 4
Strength of Poles in Bending (that is, unstayed)

Class	Length of Pole (m)	Assumed Foundation Depth (m)	Maximum Allowable Load Applied 0·6 m Down From Top of Pole, P_a (kN)
Light	6	1·2	1·10
	7	1·2	1·08
	8	1·5	1·10
	8·5	1·5	1·20
	9	1·5	1·12
	10	1·8	1·06
	11	1·8	1·10
	13	1·8	1·07
Medium	9	1·5	2·04
	11	1·8	2·05
	12	1·8	2·06
	13	1·8	2·12
	15	2·1	2·40

Note: Allowable load = load at failure/4

It should be noted that the wind load on the pole itself has not been considered in these calculated values. The wind load is small in most circumstances but should not be ignored for tall poles in exposed positions.

Buckling Case (Stayed Pole)

The use of stays relieves the bending forces on a pole and the failure mode then becomes one of crippling or buckling as a result of the high compressive force imposed on a pole by the reaction of the stay or stays. The pole is then treated as a column, and the formula used in BS 1990 is based on well-established column formulae modified to allow for:

(*a*) the effect of tapering of the pole,
(*b*) imperfect rigidity of the ground support, and
(*c*) the stabilising effect of stays and line wires or cables.

The formula used is:

$$\text{crippling load in newtons} = 0{\cdot}00411\,\frac{d_e^{\,4}}{l^2},$$

where d_e is the effective diameter (in millimetres), and is given by

$$d_e = d_t + \frac{L - D + 0{\cdot}91}{(L - 1{\cdot}5)^3}\{d_{1\cdot5} - d_t\},$$

where L = full length of a pole (metres),
D = depth of setting in ground (metres),
d_t = diameter at pole top (millimetres),
$d_{1\cdot5}$ = diameter at 1·5 m from butt (millimetres), and
l = effective length in metres from 0·3 m below the pole top to 0·3 m below the ground surface (= $L - D$).

The allowable loadings for a pole subjected to point loading, assuming a safety factor of 4, are given in Table 5.

TABLE 5
Strength of Poles in Compression (that is, stayed)

Class	Length of Pole (m)	Assumed Foundation Depth (m)	Maximum Allowable Compressive Load, P_{ca} (kN)
Light	6	1·2	15·1
	7	1·2	11·5
	8	1·5	9·9
	8·5	1·5	9·5
	9	1·5	8·2
	10	1·8	7·0
	11	1·8	6·1
	13	1·8	5·1
Medium	9	1·5	17·6
	11	1·8	13·3
	12	1·8	11·7
	13	1·8	11·9
	15	2·1	11·5

Combined Bending and Compression

If the stay is not fitted at approximately the same level as the effective point of attachment of the wires or cables (for example, Fig. 26), then the pole should be checked for bending strength at the section where the stay is attached, as well as for buckling. However, such an approach to combined bending and compression is not very satisfactory and higher safety factors are recommended.

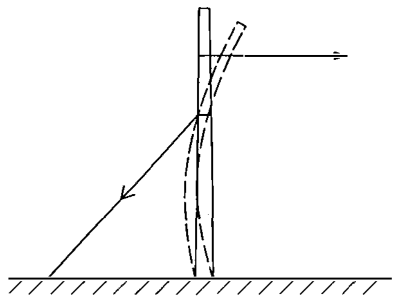


Fig. 26—Combined bending and compression case

POLE TESTING

Primarily because of the dangers to staff that can exist with a decayed or damaged pole, poles *in situ* are required to be tested for soundness to minimise the risk of pole breakage.

History

The inevitable deterioration of plant during the Second World War led to a number of fatal and other serious accidents as a result of pole breakage. Prior to 1947, Post Office Engineering Instructions referred to periodical inspection of routes rather than individual poles, although staff were required to check a pole by hammer and prodding tests prior to climbing. Such procedures were proving to be inadequate, and so action was taken and in the period 1947–1951 a crash programme of pole testing by newly-formed specialised teams was undertaken, and in that period 216 382 decayed poles were found.

The periodic testing programme, when first set up, was based on a two-year cycle in which each pole would be tested every two years, but this was soon increased to a four-year cycle in 1951; the period was again increased in 1955 to six years. The increase in time between successive tests was accompanied by making the pole examination and testing more comprehensive. A thorough review of procedures was made in the 1970s by a joint management and staff association working party under the aegis of the Experimental Changes of Practice Committee (ECOPC 1)[17]. As a result of this study, the six-year test cycle was retained, but other significant improvements were made, including the cessation of the 'S' (= suspect) category of poles.

The magnitude of the task of testing poles is considerable—during the sixth testing cycle (1974–9 inclusive), the number of poles tested each year on average exceeded 656 000 and, as a result, 32 000 poles a year were renewed.

Examination and Testing

There are two ways of ensuring that poles are safe to climb. Firstly, it is the responsibility of every officer to carry out simple but vitally important tests prior to climbing any pole (known as a *general examination*). The other means is the *periodic examination* carried out by a specialist pole-examination party.

Before Climbing

The pre-climbing general examination consists of the following:

(*a*) A check is made to see that the pole is at the correct depth by noting the location of the 3 m mark in respect of the ground level.

(*b*) A test for internal decay is made by tapping the pole with a hammer; attention is concentrated near to the ground line where decay is most likely, but with a less detailed check higher up the pole. A dull or dead note indicates decay: sound wood 'rings' clearly.

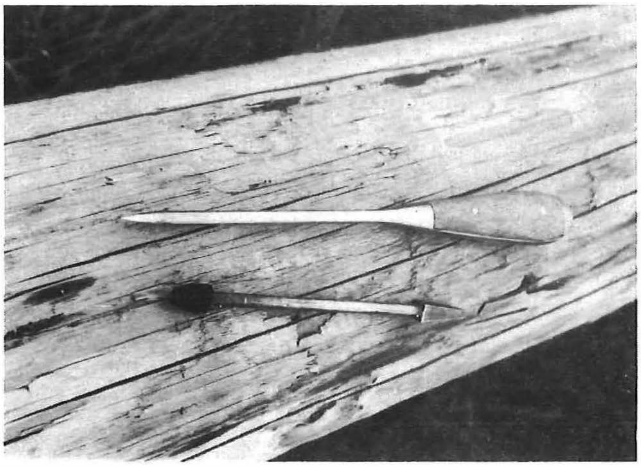


Fig. 27—Testing probe and boring bit

(*c*) Where external decay is visible or suspected, the pole is prodded with a probe (see Fig. 27); sound timber resists penetration and removal of the point, but decayed wood offers little resistance.

(*d*) A visual check is carried out for physical damage to the pole and to see that stay-wires and pole steps are correctly fitted and not corroded or otherwise damaged.

Test Cycle

All poles are examined every six years by a two-man party specially trained to give poles a more rigorous inspection and testing than can be given by the general examination. The periodic examination includes those items described for the general examination with additional tests if the pole is 12 years old or more; namely:

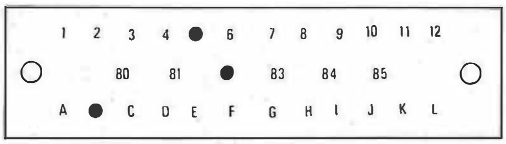
(*a*) The ground around the pole is excavated to expose the pole to 300 mm below the ground level and to test for decay by using the hammer and probe. After all surface decay has been cleared away, the exposed pole surfaces near the ground line are treated with creosote. Creosote is also poured on to the soil in the excavation before it is filled in.

(*b*) Should the hammer test give rise to doubt about the internal condition of the pole, a boring test is made by using a special bit[18] (see Fig. 27). The tool is similar to a gimlet except that the shank is of a smaller diameter than the hole made by the head. This prevents the wood from binding on the shank, and so the torque required to insert the tool is dependent on the resistance of the wood to the head alone. Rotten wood offers markedly less resistance than sound wood to the insertion of the bit. This test is used sparingly and is limited normally to one boring per pole to avoid weakening the pole or introducing seats for decay, although the borehole is plugged after the bit has been withdrawn.

On completion of the periodic examination, a pole is marked by a label which identifies the year of testing and the pole examination party undertaking the work (Fig. 28). If a pole is found to be decayed beyond the extent indicated in Table 5, physically damaged or located in a potentially hazardous position, it is marked as 'D' as a warning that it must not be climbed, and it is then renewed within 12 months. More stringent criteria on the acceptable amounts of decay listed in Table 6 may be applied if the pole is particularly heavily loaded.

Formerly, an 'S' classification (that is, suspect) was used for poles which had some decay but which were not adjudged to be unsafe to climb. Once classified as 'S', the pole was then subjected to annual testing.

Although the examination by the specialist party is very thorough, the pre-climbing procedure is vital because of the



The holes punched in the label indicate that an examination took place in May 1982 by Pole Examination Party B

Fig. 28—Pole testing label

TABLE 6
Acceptable Limits of Decay

Location	Limits
Internal	No internal decay accepted
External	Less than 6 mm deep all around pole accepted
	Isolated pockets of decay less than 30 mm deep and in pockets less than 25 mm wide around pole accepted
	No decay at pole step position is accepted

risks of physical damage, changes in ground level leading to reduced depth of burial, unusually rapid decay etc., which could cause a pole to become potentially dangerous between periodic examinations.

Similarly, the periodic examination cannot be dispensed with as the specialist party carries out a more thorough inspection and testing procedure, and checks a number of items other than those directly related to safety.

Effect of Decay on Strength

As bending stresses on a pole are the most significant, it follows that the outermost material provides the bulk of the resistance to the bending forces.

For example, the maximum acceptable decay of 6 mm depth all around a 9 m light pole would reduce the bending strength to 81% of its original value, but the equivalent volume of decay at the centre of the pole would reduce it only by a fraction of 1%. Surface decay is therefore structurally more serious, but, fortunately, it is also the simplest to identify and eradicate.

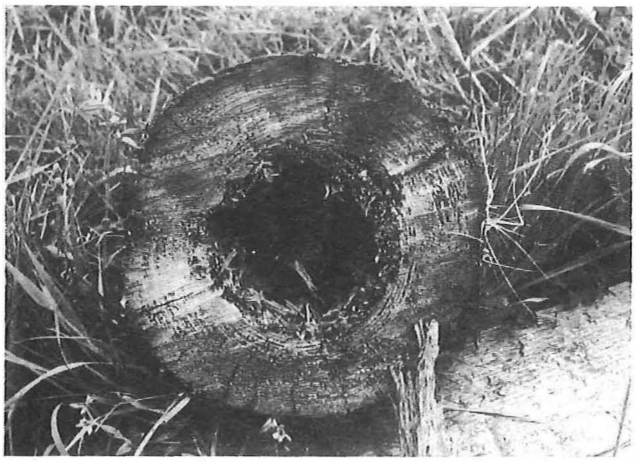
There is a marked tendency for decay to be concentrated in the vicinity of the ground line. In one survey[4], it was found that out of a total of 4210 decayed poles, 83% were decayed at the ground line. Fig. 29(*a*) shows a pole with severe internal decay, and Fig. 29(*b*) illustrates surface decay with the characteristic appearance of cracks along and across the grain of the decayed surface when dry.

Alternative Methods of Pole Testing

An alternative to the hammer test as a means of detecting internal decay has been sought for many years. The reason for this is that a large number of poles, perhaps 10% or more of those presently classified as decayed, are found to be sound when subsequently cut up. A more effective method of testing is therefore attractive economically. So far, techniques tried have not been able to detect decay with a sufficient degree of reliability. However, modern signal processing techniques hold out more hope of producing a field-usable testing system.

THE WOOD POLE—ASSESSMENT

Parts 1 and 2 of this article have considered only the wood pole. The wood pole has many attractions as a means of



(*a*) Internal decay—complete disintegration of heartwood

(*b*) Surface decay

Fig. 29—Decay in a pole

supporting overhead cables or wires. It is of modest cost and suitable trees for conversion to poles are widely available. As an item of street furniture, its life is probably greater than most. The major drawback to the wood pole is that its gradual deterioration due to fungal decay could present a hazard to staff working aloft unless appropriate action is taken. This disadvantage can be circumvented by either using a more durable material or devising a means of avoiding the need to climb poles; Part 3 of this article will deal with alternatives which have sought to tackle these issues. (*To be continued*)

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APPENDIX 1

POSITION OF MAXIMUM FIBRE STRESS (*f*) ON POLE

See Fig. 30.

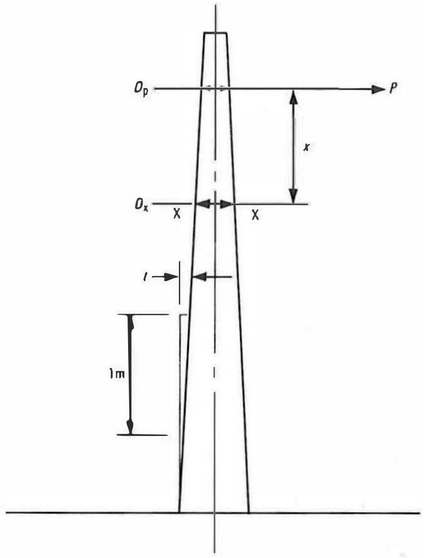

Fig. 30—Derivation of 1½*D* rule

Let D_p be the pole diameter at the load point,
D_x be the pole diameter at section XX,
t be the taper in metres/metre,
I_x be the moment of inertia at section XX $= \pi D_x^4/64$, and
y_x be the distance of the outermost fibre from the neutral axis $= D_x/2$.

Then
$$D_x = D_p + xt \qquad \ldots (1)$$

$$M_x = Px = \frac{fI_x}{y_x},$$
$$= \frac{f\pi D_x^3}{32},$$
$$= f\frac{\pi}{32}(D_p + xt)^3,$$

Rearranging,
$$f = \frac{32Px}{\pi(D_p + xt)^3}.$$

Differentiating and equating to 0,
$$x = \frac{D_p}{2t}.$$

Substituting for D_p in equation (1),
$$D_x = \frac{3D_p}{2}.$$

Thus, the most likely failure point is near to a point where the pole diameter is $1\frac{1}{2}$ times the load point diameter.

An Introduction to Mathematics for System Design

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UDC 681.3.06:51

In this first of two articles, the idea of using mathematics as a means of precise system specification is introduced. Particular emphasis is placed on the costs and benefits of the formal approach and highlights some of the important guidelines for its application. The second article, to be published later, will explain the mechanics of using mathematics in system design.

INTRODUCTION

The increase in the size and complexity of software systems has led to what is now widely known as the *software crisis*. In an attempt to overcome this problem, a range of rigorous mathematically-based design methods has been evolved.

These design methods, known as *formal methods*, enable the designer to specify and analyse the behaviour of a system as the design procedure passes from the requirements stage through to its implementation. Since the design can be proved and analysed as it is decomposed, the errors due to incompleteness, ambiguity and inconsistency are reduced. Hence the confidence that the implementation meets a given specification is greatly increased.

This article is a general introduction to formal methods and the underlying mathematics. A follow-up article will illustrate the ideas outlined here by using the specification language Z.

Firstly, the history and reasons for formal methods are explained. This is followed by a description and an example of how a formal method, namely the Vienna Development Method, should be used. Finally, the conclusions drawn from implementing such methods are presented.

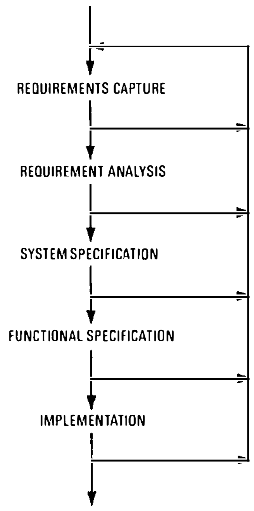

Fig. 1—Design procedure

HISTORY AND ORIGINS OF FORMAL METHODS

The reasons for developing mathematical description techniques are a direct result of the increasingly large and complex systems and software now being developed[1]. The traditional *ad-hoc* design approach to system development has the following problems:

(*a*) poor perception of the development process,
(*b*) no software engineering methods, and
(*c*) a lack of analysis techniques.

No system is developed from requirements to implementation without errors being made as the design is refined. These errors have to be corrected and the earlier the error is made in the design process the more costly it is to correct at a later stage. So if the design procedure represented by Fig. 1 is considered, it is obviously important not to make mistakes at the requirements analysis and system specification stage. Unfortunately, these two have been the least well understood areas of system development.

In the past, most requirements documents and specifications have been written in plain English. This approach leads to several problems:

(*a*) incompleteness of the specification,
(*b*) possible ambiguities within the specification,
(*c*) possible contradictions,
(*d*) the difficulty of finding the above mentioned errors, and
(*e*) the difficulty of automating the specification process.

Formal methods aim to overcome or, at least, greatly reduce the effect and number of errors introduced. Since formal methods consist mostly of discrete mathematics (that is, set theory and logic) embedded within a structure, it is possible to prove and document that certain relationships hold within the specification rather than just intuitively guessing that they do. One of the first formal methods to be used in an industrial context is the *Vienna Development Method*[2], or *VDM* in its abbreviated form. This method was developed from a wide range of formal mathematically-based techniques developed, during the 1960s and 70s, at various establishments throughout Europe and the USA.

VDM first appeared in its current form in 1973 at the IBM Vienna Development Laboratories in Austria, hence its name. Since its creation, it has undergone a variety of changes, but the concept and method have remained essentially intact. The current version is now relatively stable and is at the stage of becoming an accepted standard. STC IDEC which is developing a VDM toolset funded by the Alvey Directorate, and Professor Cliff Jones of Manchester University, have done much to bring this about. Another method[3], known as *Z*, is similar to VDM in both approach and stage of development. Z has been developed by the Programming Research Group at Oxford University, and is covered in more detail in the second article in this series.

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THE VIENNA DEVELOPMENT METHOD

VDM is a 'top-down' specification method which uses discrete mathematics to describe a system. As a result of using mathematics, it is necessarily abstract and so does not imply that any particular implementation should be adopted. The VDM specification merely states what the system should do and not how it should do it.

Format of a Specification

A specification written using VDM should be in the format of title, list of data types, list of invariants, list of states and end. This is usually laid out as shown below:

```
TITLE
LIST OF DATA TYPES
LIST OF INVARIANTS
LIST OF STATES
State 1
State 2
State 3
etc.
END
```

A state has the following format:

```
TITLE ( Input information ) Output information
        Declarations
        Invariants
        PRE-
                Any number of predicates
        POST-
                Any number of predicates
```

The title is used to identify the state. If any information is required to be input to or output from the system being specified then the input and output areas are used to assign the information to variables.

The declarations area is used to declare which variables are either read or written to in the state.

The invariants section is used to state some properties which should always be true for the state in which they appear.

The preconditions section is a list of predicates, that is a list of mathematical statements, which must be met before the following postconditions can be met.

The postconditions give the conditions of the system being specified which should be fulfilled when the state is exited. All the postconditions must be met before the state is left.

Discrete Mathematics

The type of mathematics used in a formal specification method, discrete mathematics[4], is probably not very familiar to most engineers. The discrete mathematics used in both VDM and Z can be placed into the following categories.

- Set theory
- Propositional Logic
- Lists
- Records
- Mappings

A complete definition of all the functions used in VDM can be found in Reference 2.

An Example VDM Specification

The following is a short example of a specification written using VDM. It defines a system for keeping records of the names of students enrolled in a particular class.

The discrete mathematical functions used in this example are described in the table below:

=	equality
< >	the empty list
{ }	the empty set
≈E	is not an element of a set
U	the union of two sets
E	is an element of a set
–	removal of an element from a set

The following VDM example defines the operations within the state called *class-state*

```
                                                          Line
                                                        Number
Class-State is                                               1
            studentname = char-list                          2
            class = studentname-set                          3

            EACHSTUDENT : studentname                        4
            PHYSICSCLASS : class                             5

INIT                                                         6
        EACHSTUDENT : wr studentname                         7

        PHYSICSCLASS : wr class                              8

        post                                                 9
            eachstudent = < >                               10
            physicsclass = { }                              11

ENROL ( EACHSTUDENT : studentname )                         12

        EACHSTUDENT : wr studentname                        13

        PHYSICSCLASS : wr class                             14

pre                                                         15
        eachstudent ≈E physicsclass                         16

post                                                        17
        physicsclass' = physicsclass U eachstudent          18

EXPEL ( EACHSTUDENT : studentname )                         19

        EACHSTUDENT : wr studentname                        20

        PHYSICSCLASS : wr class                             21

pre                                                         22
        eachstudent E physicsclass                          23

post                                                        24
        physicsclass' =                                     25
                    physicsclass – {eachstudent}

        END                                                 26
```

The following is a brief explanation of the very short specification given above.

wr - means write to

Line 1:	'Class' is the name of the specification; 'State **is**' is an identifier to make the name visible.
Line 2:	'studentname' is being declared as a new type 'char-list'; that is, a list of characters. 'char' is a predefined type in VDM and is a single character.
Line 3:	'class' is being declared as a new type 'studentname-set'; that is, a set of studentnames. This illustrates the ability to define your own data types consisting of other types. Type 'class' is therefore a set of character lists.
Line 4:	'EACHSTUDENT' is a variable being declared to be of type 'studentname'.
Line 5:	'PHYSICSCLASS' is a variable being declared to be of type 'class'.
Line 6:	'INIT' is the name of the following state.
Line 7:	This declares that the variable 'eachstudent' of type studentname can be written to or read.
Line 8:	As above, but using 'physicsclass' and 'class'.
Line 9:	This line declares that the following statements form the post condition for the state.
Line 10:	'eachstudent' must be equal to the empty list.
Line 11:	'physicsclass' must be equal to the empty set.
Line 12:	This says that the name of the following state is 'ENROL'and that information is being written to the variable 'eachstudent' of type studentname from outside the system being specified.
Line 13:	As line 7.
Line 14:	As line 8.
Line 15:	This says that the following statements form the precondition of the state. This must be met before the post conditions can be met.
Line 16:	This says the student name must not already be a member of the set 'physicsclass'.
Line 18:	This says that when the state is exited the new 'physicsclass', that is, 'physicsclass′' must equal the old physicsclass union with the the new studentname. This effectively adds the student name to the class set.
Line 23:	This states that eachstudent must be a member of the set physicsclass, as in order to remove a student, that student must first have been enrolled.
Line 25:	The post condition for EXPEL says that the new physicsclass, 'physicsclass′', must equal the old physicsclass with the name of the expelled student removed.
Line 26:	This signifies the end of the specification.

Although this example specification is consistent it is not complete. For example, there is no means of retrieving the names of the students who are enrolled in the class. There are also no invariants given in the example, though this is because none are applicable.

A RIGOROUS APPROACH TO SOFTWARE DEVELOPMENT

In the previous section, the syntax of VDM which is necessary to write down the specification was outlined. The development of software requires more than this. A means of using and manipulating the specification language with design rules common to many other methods is also required. The following is a brief schedule of the rigorous approach.

Specification; Use a properly documented algorithm, if available, otherwise

choose a data type to match the problem
document data type invariant
show that validity is preserved
develop theory
prove that the properties match the intuitive view

Development; Either refine data types or decompose operations | Repeat until implemented

Improve; Specification
Development

Before a system is specified, it is *essential* that the problem, which the system is to solve, is completely understood. Only then is it possible to begin writing the specification. Large systems can thus present some problems because usually they must be decomposed into smaller units to make this understanding possible. The first level of decomposition is the most difficult to perform correctly.

The specification begins with a check to see whether any useful information is already available. Any such information or algorithm must be properly documented, before it is used, as a solution which is badly documented will be difficult to fit into a new environment. Usually, most of the specification will undoubtedly have to be written as completely new material.

The next step is to choose a suitable data type: one which matches the problem and minimises the number of data-type invariants required. On large specifications, data-type invariants are an essential part of checking for consistency. Matching the specification to the intuitive view of its function is never easy, but the use of formal methods gives at least some hope for the user to gain confidence. Informally defined specifications can instil confidence by stating the properties of the system. This confidence is often sadly misplaced.

The development stage is an iterative process and involves repeated decomposition and refinement. Although the process is nominally top-down, developers should feel free to sketch far ahead, revise, or even perform some 'bottom-up' development. The overall process should be top-down. Once an earlier design decision is found to be erroneous, designers should not be prevented from discarding it and starting again if necessary. If faced with a decision as to which development step to take, refinement should be given preference over decomposition, since the latter tends to fix the order of operations. It is important to avoid trying to do too much in one step, and this should always be borne in mind.

SUPPORT FOR FORMAL METHODS

One of the main reasons for approaching any of the recently developed formal techniques with a certain amount of caution is the lack of support. There is a heavy dependence on the skill and experience of the design team in using the method to its best advantage, and projects employing any of the methods can become 'opaque' to external review. Of the formal methods which have been used, VDM and Z have the best industrially-oriented backup, both in terms of documentation/training and in their prospects for automated support tools.

Training

The amount of training required to enable someone to become proficient with formal methods would depend to a great extent on their mathematical background. Most hardware and software engineers would require some of their ideas to be radically altered to cope with the concepts of formal methods. Mathematicians would need less training as they already work in an abstract world. The subject areas in which most engineers would require instruction would be:

(*a*) the theory underlying the method,
(*b*) discrete mathematics,
(*c*) the syntax of the method, and
(*d*) how the method should be used.

Between two and three weeks would probably be required before someone could begin to write syntactically correct specifications and another two or three months to become proficient.

It is difficult to understand how to tackle a specification without a more knowledgeable person at hand to explain the approach. Learning any formal method from books is extremely difficult and time consuming, so until universities begin teaching related subjects at undergraduate level, the training burden will, initially, be quite heavy.

Tools

There are very few tools presently on the market which are addressed at making the writing of specifications easier or quicker. There are projects funded by the Alvey Directorate to create toolsets for both VDM and Z, but these will not be ready for at least two years.

With the arrival of more 'intelligent' tools such as theorem provers, it should be possible to show that a specification is at least consistent and non-contradictory within itself. These types of tools, though several are in existence at present in an experimental form, will take some time to apply to formal specifications. In the meantime, proofs will have to be conducted manually.

USING FORMAL METHODS

It is all very well understanding the principles of the method, but when it comes to starting a new specification, inexperienced users rarely start in the right place. These guidelines, based on several case studies in VDM and Z should direct inexperienced users towards a good application of formal methods.

Guidelines

Abstract Or Vague ?

Although abstraction is an integral part of VDM and Z, it is quite possible to be so abstract that the specification is just vague. The only real solution to this is experience. A good rule of thumb, however, is to start off using mappings to define relationships and then to transform these into less abstract data types as the design becomes more definite.

Decomposition

For VDM and Z, this should be performed by using data abstraction properties and not functions. Decomposition should take place on the basis of what the states work with rather than what they do.

Preconditions

Preconditions are normally used to specify the conditions which must hold in a system before the postconditions can be met. Preconditions are not essential to most states as they can be included in the postconditions. Preconditions do have a use when a specification which is far away from its final form is being developed. They impose more constraints on the system than the postconditions and make the conditions explicit rather than being implicit and possibly difficult to see.

Invariants

Invariants can be used as a measure of the level of abstraction; the fewer invariants contained within a specification the nearer the specification is to an implementation level. This is a function of the process of refining data types.

Common Misconceptions

As it is mainly systems designers and programmers who will use this method, it is useful to bear the following points in mind, as they are often a source of confusion.

Predicates And Assignments

VDM and Z state their pre- and postconditions using predicates. People who have a programming background often confuse predicates with assignments as used in many programming languages. A predicate is a statement: it specifies the state of the system at that point; it is not a command that tells a computer what to do.

Specification Not Implementation

The pre- and postconditions merely state what the system should do and not how it should do it. This is another misconception sometimes held by those with a programming background. It is not necessary to show an algorithm which, if followed, will fulfil the postcondition. Only the end result need be stated. This will give short and more easily understood specifications; it should not be necessary to state explicitly how the postcondition will be met.

CONCLUSIONS

The final decision on whether to use a formal method on a project depends on two simple questions.

(*a*) Is it appropriate for this application? and
(*b*) Do the benefits outweigh the costs?

The first question cannot be fully answered here, since no two design situations are the same. However, the information in Table 1 below should enable a reader to estimate whether formal methods are applicable to his problem.

TABLE 1

Reference Table for VDM

Application	Specification and development of sequential programs
Characteristics	Notation based on abstract data types Based on successive refinement of data model Proof obligation to justify refinement steps
Status	Stable syntax and semantics Text Books/Training Courses/Case Studies
Limitations	No explicit handling of concurrency Does not address timing, performance etc. Not readily integrated with other design techniques
Prospects	Automated tools (1987) Extensions for time ordering
Comments	Mature method that has received widespread use but requires commitment of time before benefits accrue
Similar Approaches	Z

Consider now the points raised by the second question by looking at the likely benefits and costs.

Costs

Training A basic course which enables one to write a formal specification in VDM or Z is two-weeks long.

Experience Learning the syntax and semantics of a method is only the first step and it is probably at least two months before useful work emerges.

Visibility A formally based project is not easy for external sources to review without special briefing. The method may aid unambiguous communication within a select group, but will probably detract from it outside that group.

Management It is difficult to measure progress. This is mainly due to a greater part of the project being dedicated to specification, but it does require an appreciation of the eventual benefits by those applying the short-term pressure. It should also be noted, however, that it may be better to throw away a bad specification and start again.

The Benefits Gained From Using Formal Methods

Clearer Thought Encourages the designer to think about the specification. This gives a more correct specification and early identification of inadequate problem definition. If a problem cannot be written formally, it is not thought out well enough.

Communication It provides an unambiguous specification. A few days training is sufficient to appreciate either VDM or Z.

Verification Allows justification of all the design decisions. It tackles problems of verification and validation.

Communication Provides good documentation for back-tracking and isolating faults.

So far, the methods have been discussed only in general terms. It has been stated how good they are and when they should be used. The second article in this series will show how to apply a formal method in practice.

Acknowledgements

The authors would like to thank the many colleagues at BTRL who have contributed to this work.

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Biographies

Paul Newman obtained his B.Sc. in Electrical Engineering from Hatfield Polytechnic in 1984. After graduating, he joined the Advanced System Design Techniques group at BTRL, where he has been responsible for assessing the application of formal methods to system design. He is currently working on a collaborative project with NTT, Japan, to build a system design environment.

Peter James graduated from Hatfield Polytechnic in 1984 with a B.Sc. in Computer Science and subsequently joined the Advanced System Design Techniques group at BTRL. He is responsible for the development and application of formal design techniques which enhance the system design process. He is currently involved in the NTT collaboration and the development of a formal specification and code library.

Mark Norris received his B.Sc. and Ph.D. degrees from Glasgow University in 1976 and 1979, respectively. He then joined BTRL to work on local network signalling systems and interfaces. His work since then has encompassed the design and implementation of the ISDN, high-speed local area networks and interface test equipment. He currently heads the Advanced System Design Techniques group.

From Time to Time

A Review of Past Journals

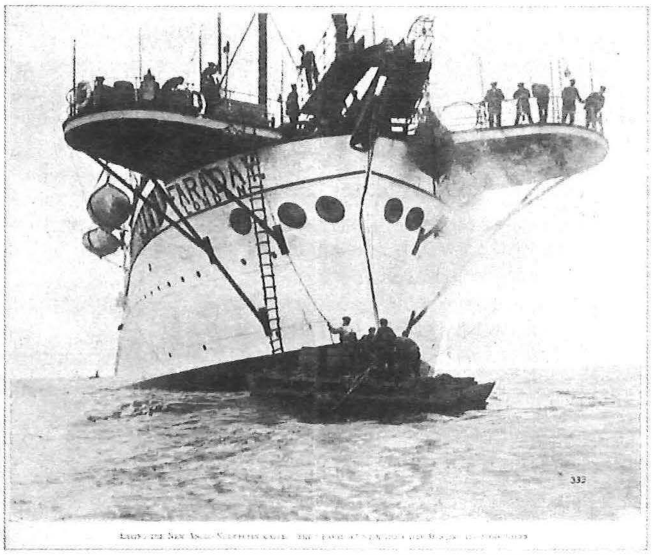
INTRODUCTION

From time to time, some of the events, innovations and equipment as reported in the *Journal* 25, 50 and 75 years ago will be reviewed.

75 YEARS AGO—Vol. 3 January 1911

Submarine cables, Wheatstone and Baudot telegraph working and a review of the early history of wireless telegraphy working were among the subjects covered in the January 1911 issue of the *Journal*.

Faraday was also in the news at this time, not, as at present, in terms of the Faraday Lecture, but in the guise of the cable ship *Faraday* engaged in laying a new telegraph cable between England and Norway.

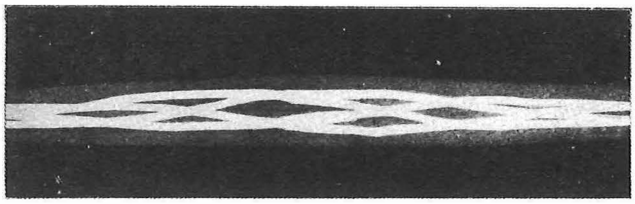


Cable Ship *Faraday*

Submarine Cables

The new England–Norway telegraph cable was the fifth to land at Newbiggin, some 20 miles from Newcastle-upon-Tyne. The cable was reported as being 410 knots in length with a seven-strand copper conductor core weighing 200 lb per knot, covered with gutta-percha also weighing 200 lb per knot. Over this was wound a brass tape to give protection against *teredo* and other boring worms. A feature of the installation was that the shore end was not rafted ashore as was usual, but was hauled ashore by rope, the cable being kept afloat by lashing it to empty barrels.

The *Journal* also included an abstract of a paper given by Major O'Meara (the Engineer-in-Chief) to the Institution of Electrical Engineers (IEE) on 'Submarine Cables for Long-Distance Telephone Circuits'. This paper described some of the development work on submarine cables from the time of the first telephonic cable between St. Margaret's Bay and Sangatte, France, in 1891. There is much discussion on the relative merits of continuous versus lumped loading as a means of improving transmission performance. Reference is also made to the use of Röntgen rays for the examination of joints in the Anglo-Irish cable in 1898.



Radiogram of joint in air-spaced gutta-percha cable between Wales and Ireland

Telegraphs

The introduction of 'Systematic Wheatstone Working' on the London–Edinburgh route is described. The main feature of the system was that the Wheatstone slips, the paper tape recording the incoming signal, were gummed onto message forms immediately on receipt before being passed forward for onward transmission or to be typed if they were for local delivery. The net result of this change was that not only could a single line now handle all the traffic between the two cities (about 2000 messages per day), but several other direct routes to Scotland could be closed and the traffic circulated via Edinburgh. This gave an annual saving in maintenance charges of £5000 and helped reduce the average delay from 60 minutes to 10 minutes.

This issue also contained 'The Baudot Telegraph System Duplexed'—a description of an enhancement to the well-known printing telegraph system. The main advantage of this system was that no perforated slip had to be handled (it must be remembered that, with Wheatstone working, 20 feet of perforated slip was equivalent to 100 words). The Baudot system could handle 160 words per minute on a 200 mile circuit compared with 100 words per minute with Wheatstone working.

A continuation of an account of 'The Early History of Wireless Telegraphy', by Mr. J. E. Taylor, who worked closely with Guglielmo Marconi during the trials with the Post Office, includes notes on the development of closed-circuit transmitters and investigations into methods of coupling.

Notes and Comments

Paris Conference 1910

The six sections of work covered by the Second International Conference of European Telegraph and Telephone Engineers, Paris, September 1910, was reported in the *Journal*.

(*a*) *Automatic versus Manual Telephone Services*
There was much discussion on the economics of the alternative systems and the problems of accommodating PBXs on automatic systems.

'Major O'Meara said that according to his views an automatic system—that is, a system in which none of the operations of establishing a connection were dealt with manually, would not be entirely satisfactory except in special cases. But there were many localities in England where the necessary staff cannot be obtained to give a permanent telephone service, and at these places the automatic exchange would fill a want. In general, it was necessary to have human intelligence at some point in the working. He considered that the ideal system would be one in which the A operator was retained to deal with the calling subscriber, as this would leave the operations to be performed by the subscriber as simple as possible, and in which every other operation in establishing the connection was automatic.'

(*b*) *Standardisation of Telephone Circuits* 'The recent developments in the theory of telephone transmission have made it possible for the efficiency of the telephone circuit to be expressed in terms of some particular type of circuit, which is taken as the standard.

'Such a method of expressing the efficiency of a circuit is, however, not very scientific, and it is very important to chose some method which will be independent of any particular type of standard cable.

'The current [*C*] at any point of a telephone circuit *l* miles from the sending end is expressed by the following equation:

$$C = C_0\, e^{-\beta l} \times e^{-i\alpha l}.$$

'If *l* be the total length of a circuit, the quantity βl, therefore, determines the loss of intensity of the speech on such a circuit. It is proposed to use the value of βl to express the efficiency of a telephone circuit—or rather, its want of efficiency—instead of saying that the circuit is equivalent to so many miles of standard cable.

'The constants β and α which come into the transmission formulae involve the frequency of the current. Since the form of the telephonic speech wave is extremely complex it is necessary to agree upon some definite frequency which can be used in calculations, in order to avoid misunderstandings in the comparison of results.

'Several suggestions for the best value for this frequency were discussed, that finally adopted being 800 periods per second.'

(*c*) *Co-existence of Lines Carrying Strong Currents with those Carrying Weak Currents* 'The question of legislation in connection with such interference was discussed, and the proposition was made that an international agreement should be drawn up defining the minimum protective devices to be applied to prevent damage. It was pointed out that in the case of long international telegraph and telephone circuits it was no use adopting an elaborate scheme of protection in one country if in an adjacent country the conditions were much more lax.

(*d*) *Long-Distance Telephony* 'The question of loading by the insertion of Pupin coils or by uniform loading on the Krarup system was discussed.

'On the continent the general opinion appears to be in favour of continuous loading, but in this country we have, up to the present, found that the insertion of Pupin coils gives far better results. [Dr. Michael Pupin started life as a shepherd boy in Serbia and rose to be Professor Emeritus of Electromechanics at Columbia University. Among his many scientific developments and inventions was the Pupin loading coil.]'

(*e*) *New Processes for the Preservation of Wooden Poles* 'In Austria the boucherising process, which consists of the injection of a solution of copper sulphate, has been found to be not sufficiently reliable, and creosoting has been adopted.

'In order to avoid the difficulties of creosoting, by reason of the high price of creosote and the oozing out of the material from the timber, a new method of impregnating the wood has been devised. The amount of creosote applied to the wood is only one half that used by the ordinary method. After the creosote has been absorbed, the pole is placed in an atmosphere of steam under pressure. This high pressure cleans the outside of the pole and forces the creosote into the interior.

'This process commenced in 1904 and has given very satisfactory results. But the process is only practically applicable to fir poles (*Pinus sylvestris*), and also the southern parts of Austria are so hot in summer that creosoted poles cannot be used. The Austrian Government have therefore tried other antiseptic treatments, such as injections of fluoride of zinc, a mixture of chloride of zinc and fluoride of sodium, fluoride of sodium alone, and a mixture of fluoride of sodium, dinitrophenol and aniline.

'They have also used bases to the poles made of reinforced concrete.

'The French Government mainly use boucherised poles. They recognise that this method of protection is insufficient to protect the upper portions of a pole from decay if nothing further be done, and therefore the tops of the poles are covered with a coat of paint. Pole roofs are not used in France. They also find that when the ground in which the pole is fixed contains micro-organisms which can injuriously affect the wood it is necessary to supplement the copper sulphate treatment, and for this end they inject an antiseptic liquid known as *injectol* into the base of the pole.

'The French Government also make use of pole bases of reinforced concrete, but only in special cases.

'The Engineer-in-Chief of the Dutch Telegraph Service gave some statistics of the life of poles treated by various preservative processes: creosoted poles, 20 years 6 months; (copper sulphate) boucherised, 15 years; (mercuric chloride) kyanised, 13 years 7 months; (zinc chloride) burnettised, 11 years 9 months. He stated that by reason of the inconveniences caused by the use of creosote, the Dutch administration prefer to employ boucherising to protect the poles used on their system.

'In Germany, pole bases of reinforced concrete have recently been adopted on a large scale.

'They are used in soils which contain organisms particularly harmful to wood, and also to prolong the life of a pole which has decayed at its base.

'These concrete pole bases are found to resist well the stresses caused by gales and snowstorms.'

(*f*) *Telegraph Systems of Large Output* Apparently four papers were submitted, but two had no direct bearing on the question. The other two proved too extensive to summarise, but copies were reported as being available from the Institution's library.

The Postmaster-General's Annual Report

The Postmaster-General's Annual Report for 1910 showed that telegram traffic had increased by 2·4% to 86 884 000 telegrams, but still made a net loss of £1·02M with an income of £3·1M. The trunk telephone network was reported to have 643 trunk exchange lines, 2666 trunk circuits and carried 26 566 318 calls. There were 64 200 subscribers in London and 23 635 in the provinces. Despite an income of £1·7M, the telephone service made a loss of £71 973.

The Journal in Russia

It was reported that extracts of *Journal* articles had appeared in Russian journals. It may interest readers to know that copies of abstracts, in Russian, of *Journal* articles are still received from the Soviet Union.

Local Centre Notes

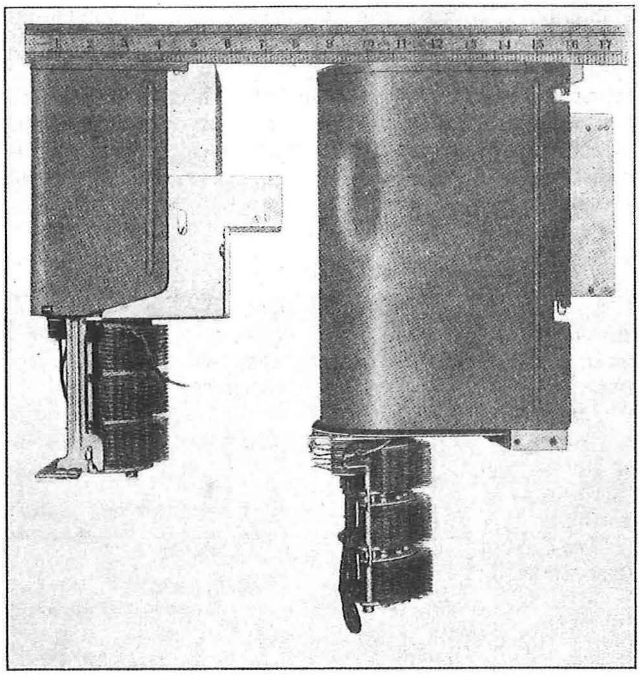
It was recorded in the Notes that the Metropolitan Centre would henceforth hold its meeting at the IEE Building, Savoy Place, and that membership of the Scotland East Centre had reached 100%.

A lecture on the 'Unit Maintenance Cost System' by Mr. R. Gold provoked healthy debate at many centres. 'The unit maintenance cost system work is sometimes looked upon in the provincial districts as somewhat unproductive, if not useless, but, as the lecturer endeavoured to impress upon his hearers, "the point of view" makes a considerable difference, and there is now less doubt in the minds of those who had the pleasure of hearing Mr. Gold that the resultant figures can be, and are, put to useful purpose at Headquarters.'

Other lectures included 'Selenium: Photo-Electric Effects and Photo-Telegraphy', 'Testing Paper-Core Underground Cables During Construction', and 'Secondary Cells'.

50 YEARS AGO—Vol. 28, January 1936

Despite Major O'Mears's earlier reservations, by 1935, automatic exchanges served 38% of all exchange connections, split equally between director and non-director working. This rapid transition to automatic working had taken place over the previous ten years. During this period, it became increasingly obvious that some measure of standardisation was necessary in terms of both equipment and accommodation.



Comparative sizes of 2000-type and 'Strowger' selectors

Standardisation

Telephone Exchange Standards

Various standards had been introduced for telephone exchange buildings and switching apparatus. Four standard buildings, Type A, Type B, Type C1 and C2 were available for Unit Automatic Exchanges (UAXs) to accommodate the UAX12 (100 lines), UAX13 (200 lines) and UAX14 (800 lines). For larger buildings, standardisation of apparatus room heights, cable lead-in arrangements and ventilation systems had been adopted. Automatic control of humidity in certain unattended exchange buildings by means of electric heaters was under consideration.

Other innovations included the introduction of travelling ladders fitted with automatic brakes and capable of being reversed in the gangway, and the provision of mezzanine platforms for large main distribution frames. On the intermediate distribution frame, the horizontal mounting of tag blocks on one side had been abandoned. This change resulted in fewer faults caused by dust, wire clippings or blobs of solder.

Cabling and wire had also undergone some changes; the range of braided switchboard cables had been extended and a new jumper wire had been introduced. This new wire was tinned, double acetylated-cotton covered and cellulose-acetate lacquered. It was hoped that this would overcome the problem at some exchanges of attack on the insulation by the cloth moth.

'The possible use of "Seekay" wax for impregnating switchboard cable forms and wires, instead of beeswax, is under consideration. It is non-inflammable and resists attack from insects.'

Two other major items of exchange equipment were introduced during this period: the 3000-type relay and the 2000-type selector.

The Post Office 2000 Type Selector

A new design of selector was considered necessary because of the problems being experienced with the many different designs of 'Strowger selectors' then being used.

'This attempt at standardisation was postponed while trials of new systems, employing uniselectors, were in progress. Meanwhile, Messrs. Automatic Electric Company were developing a new type of two-motion selector, and, when it was decided by the British Post Office not to depart from the two-motion selector system as standard, this new type of selector was adopted.'

The 3000-type relay was designed to meet the exacting and complex requirements of automatic telephone circuits and was used in the 2000-type selector. Also introduced at this time was the 600-type relay. This relay, the 'little brother' of the 3000-type, was intended for more general applications.

Precut Poles

To a lesser extent, standardisation had been applied to poles. The usual practice was for all drilling, slotting, and trimming at the tip to be carried out on site. 'It will be realised that such cutting and drilling penetrated the protective sheath of creosoted wood which forms the outer surface of the timber, and a system of preparing poles at the Pole Depot, before the pole is creosoted, would not only save time in the field, but also minimise the chances of decay.'

The precutting of poles had been considered previously, but was discounted owing to the variable shrinkage encountered during seasoning.

The new approach was to cut a flat of suitable length on the pole and drill it to accommodate the arms, extra rigidity being provided by the use of galvanised mild-steel arm braces.

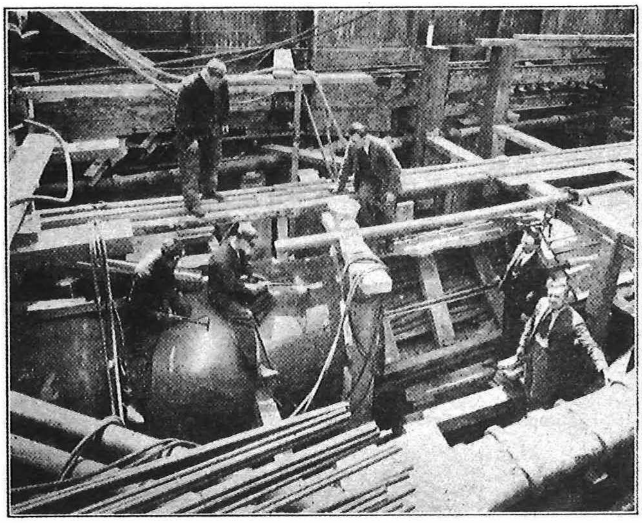
External Construction

Recent Underground Diversion works in London

Modernisation of the London Transport underground railway system posed many problems for the Department. In many cases booking halls, usually situated under road junctions, were being extended, and this necessitated the diversion of underground plant. Two diversions in particular were reported in the *Journal*.

At Chancery Lane Station, situated at the junction of Grays Inn Road and Holborn, it was necessary to divert 107 main cables with the change-over of 12 000 pairs, most of which carried working circuits, including some with phantom and double phantom circuits.

An item of particular interest at the site was the old parcels tube, a metal tube which had been laid some 74 years previously for the transport of parcels on waggons propelled by atmospheric pressure. This tube contained 50 main trunk and junction cables and was right on the line of the new booking hall.



Removing the old parcels tube during modernisation of Chancery Lane Underground Station

At Leicester Square station, 43 000 pairs of wires were changed over and 51 tons of scrap cable recovered. The problems at this location necessitated the building of two new subways below the level of the new booking hall at a depth of 45 feet to accommodate the various public utilities.

Asbestos-Cement Duct

The manufacture of asbestos-cement duct is described together with details of a trial installation at Fenny Stratford.

Notes and Comments

An Interesting "Wire" Broadcast

'On Tuesday, October 8th, meetings were held by the Junior Section of the Institution of Post Office Electrical Engineers at their Eastern District Centres in Cambridge, Norwich, Ipswich, Colchester, Fenny Stratford, and Bury St. Edmunds, and these meetings were addressed simultaneously by the aid of the cable network and loudspeakers, by Capt. N. F. Cave-Browne-Cave, the Superintending Engineer of the Eastern District, speaking from his home. Capt. Cave was followed by Mr. W. M. Osborn, the Assistant Superintending Engineer, and by Mr. C. W. Brown, who is President of the Junior Section.

'This event provided a good example of the ease with which several scattered audiences can nowadays be addressed simultaneously by a single speaker, a facility which is likely to appeal to many other organisations.'

The Telecommunication Journal of Australia

The *Telecommunication Journal of Australia* celebrated its Golden Jubilee in 1985, and 50 years ago its inauguration by the Postal Electrical Society of Victoria was reported in the *Journal* with an extract from the 'Foreword' by Mr J. M. Crawford, the Chief Engineer of Victoria. This was not an entirely new venture for Mr. Crawford because 27 years earlier he had played an active part in the formation of the Institution of Post Office Electrical Engineers and was its Secretary from 1908–1910.

FOREWORD

THE purpose of a foreword in a venture of this kind is, I suppose, to send it forth with every initial good wish—a sort of literary breaking of a champagne bottle on the prow of this our Victorian Technical Argosy as she takes the water for her maiden voyage. If that be so, then very sincerely do I contribute my word of Good Luck and Bon Voyage.

I well remember, as Secretary of the Institution of Post Office Electrical Engineers, helping to launch a Journal which, at its inception, was equally modest, and which we sent forth with equal trepidation. Its first issue was on All Fools' Day, 1908, and there were some who facetiously connected the date with the venture; but to-day the Journal is probably the premier Telecommunication Journal of the World—"The Post Office Electrical Engineers' Journal." It also started from small beginnings and from a sense of the need which British Post Office Engineers were then feeling of some vehicle by which they could pool and share their engineering knowledge and experience. For the true Scientist and Engineer is never selfish or exclusive. He is glad to bring his contribution into the common hive of knowledge and place his observed data at the disposal of his fellow-workers, whether they be workers in the realm of inductive thought, research or practical engineering. The value of a Journal of this kind to our Engineers is emphasised in another article in these pages, but may I stress one vital truth—it is only possible to achieve success in a Journal of this kind by widespread and consistent support!

So, just as 64 years ago the Society of Telegraph Engineers in London founded the great Institution of Electrical Engineers with its world-wide membership and authoritative Journal, and 27 years ago the Engineers of the British Post Office founded the Post Office Electrical Engineers' Journal, which to-day has also a world-wide circulation, so may our Victorian venture be a prelude to an All-Australian Communication Journal, which in due time will increase in value and become the authoritative record of the steady progress of Communication Engineering in Australia.

Above is the Foreword which appeared in the first issue of this Journal in June 1935.

Reprinted from the Golden Jubilee Edition of ***The Telecommunications Journal of Australia***

Regionalisation

In 1932, the Bridgeman committee had reported on its enquiries into whether any changes in the constitution, status or system of organisation of the British Post Office would be in the public interest. The report said that a large measure of decentralisation should take place and that activities in a given territory should be controlled by a Regional Director. In 1935, two experimental Regions were established (Scotland and North East) to test in detail the practicability of the scheme.

District Notes

Storm damage was reported in Scotland West where 228 exchanges were isolated with faults on 776 trunk lines and 9000 subscribers' lines. Almost the entire damage consisted of trees or branches falling on overhead lines and bringing them down. At Dalmally, a wooden shed was found draped over the top of a telephone pole.

The London–Birmingham 0·45 inch coaxial cable was installed, and the Nantwich unattended amplifier station, containing 20 Unit Amplifiers No. 6 providing 20 physical circuits plus 20 carrier wave circuits, was brought into service.

In Plymouth, during construction of the duct route for the experimental Bristol–Plymouth multi-channel multi-conductor carrier-on-cable system, an unrecorded stone structure was encountered. This proved to be a water tunnel constructed by Sir Francis Drake in 1590 that was still in occasional use for overflow water from Drake's Place reservoir. The water authority gave permission for 42 feet of steel pipe to be placed in the roof of the tunnel to carry the duct route.

25 YEARS AGO—Vol. 53, January 1961

By 1960, 80% of exchange connections were served by automatic exchanges, but subscriber trunk dialling was available to only 0·16% of these connections. Conversion of the Telex service to automatic working had been completed. Also in 1960, the cable pressurisation scheme was extended to include local cables from exchanges to cross-connection cabinets. The use of polythene was being considered for larger cables.

Polythene-Sheathed Underground Cables

'Small cables insulated and sheathed with polythene have been used sucessfully in local distribution networks for some time, and such cables have been adopted for general use in sizes up to 100 pairs. The use of this type of cable in sizes up to 2000 pairs is being tried experimentally.'

Two major problems needed to be overcome with this type of cable: the first was the difficulties encountered in making satisfactory joints in the sheath; the second was the permeation of water vapour through the outer sheath. Various methods of jointing these cables were being evaluated, but the problems of water penetration had largely been solved.

A Moisture Barrier for Polythene-Sheathed Cables

'The new sheath derives its resistance to the permeation of moisture from a layer of aluminium foil firmly bonded to the inner surface of the polythene. Suitable foil, about 0·003 inch thick, is commercially available already coated on one side with a layer of polythene by a hot extrusion process which produces a very strong adhesion between the two materials. This laminate is applied to the cable core with its polythene surface outward, so that, when the resulting assembly is covered with polythene by extrusion, the sheath welds to the coating on the foil whilst still hot, thus firmly bonding the foil to substantially the whole of the inner surface of the sheath.'

Protection of Exchange Equipment and Subscribers' Installations from Damage Due to Lightning and Contacts with Power Lines

This article traced the development of protective devices fitted at exchanges and subscribers' premises since the fuse, the heat coil and the lightning protector were adopted as standard in about 1900.

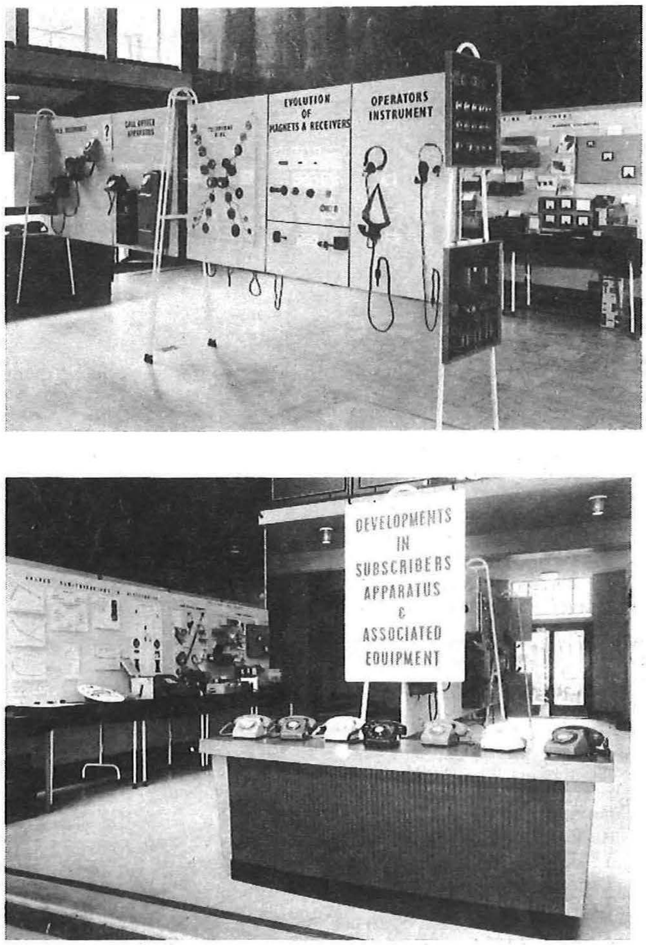
Four New Engineering Vehicles

Four new vehicles ranging from the Morris Minivan to the 30 cwt utility van were introduced. The two smaller vehicles were standard, and required only minor modifications, but the larger vehicles had purpose-built bodies mounted on a standard chasis.

15 cwt utility van

Exhibition of Subscribers' Apparatus and Associated Equipment at 2–12 Gresham Street, London, E.C.2

'With the increasing specialisation of many Branches of the Post Office Engineering Department it is becoming more difficult for the staff to keep abreast of current developments and practices. One suggestion for overcoming this difficulty has been that certain Branches should hold small exhibitions of current developments and practices in the entrance hall at 2–12 Gresham Street, the headquarters of the Engineering Department.'



Exhibition of subscribers' apparatus at Gresham Street

Signal Transmission Across the Atlantic via a Passive Earth Satellite

On 12 August 1960, *ECHO 1*, a passive reflector satellite for experimental long-distance communication was launched. It was agreed that the Research Department would build a suitable receiver in an attempt to establish transatlantic communication during the nominal 12 minutes of simultaneous visibility. A major problem, however, was the availability of a suitable aerial. Fortunately, the Royal Radar Establishment at Malvern was able to produce a 20 ft diameter parabolic reflector complete with a mounting which enabled the reflector to be steered manually. The first few days, and nights, after the launch were occupied in tracking the satellite optically and practising the complex co-ordination involved in steering the aerial and adjusting the receiver. By the night of 29 August, all was in order for the test, and it was reported that when the first signals were received exactly on time, 'it was also most encouraging to find that signal levels were as predicted from theoretical considerations and that all the complex equipment worked most satisfactorily.'

International Symposium on Data Transmission, Delft, 1960

'As the size, speed and expense of modern computers grow more formidable every year, it has become increasingly advantageous for organisations to have one central computing centre and to feed data from outstations over telegraph and telephone circuits to the computer for processing.'

It was an interest in this aspect of data transmission that attracted over 500 engineers to the symposium. Twenty-five papers covering error rates, error detection and correction and data transmission systems were read.

'There were many differences of opinion as to the best measure of errors. Various authors quoted: error-free minutes; character errors in terms of errors per x characters or the number of characters per error; and block error rates, expressed as blocks in error per x blocks.'

Regional Notes

In the Midland Region, an experimental pitch-fibre duct was used to provide a watertight lead-in to Rubery New ATE, and in Birmingham major roadworks dictated that a cable tunnel would be required at Telephone House.

At Doncaster, contruction of the Doncaster Motorway involved the construction of 32 bridges, 14 of which affected existing duct routes.

A plug-in telephone trolley was constructed by engineering staff in Wrexham for use at the Wrexham War Memorial Hospital. The trolley was designed to accommodate either the existing prepayment coinbox or the new pay-on-answer coinbox.

Notes and Comments

It was reported that difficulties had been experienced with the introduction of the Deductions-from-Pay scheme for Post Office readers, but that arrangements were in hand for it to commence in April 1961. Readers were urged to complete the necessary forms by March 1961. In view of the current difficulties in obtaining readers' home addresses, the request might seem a little ambitious (at the time of writing, less than 50% of BT readers have responded to the request made some 6 months ago for details of mailing addresses).

Forthcoming Conferences

Further details can be obtained from the conferences department of the organising body.

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

Computerised Quality Assurance
23–26 March 1986
University of Sussex, Brighton

Speech Input/Output; Techniques and Applications
24–26 March 1986
Institute of Education, London

Software Engineering for Telecommunication Switching Systems
14–18 April 1986
Eindhoven, The Netherlands

Communications—An Industry on the Move (COMMUNICATIONS 86)
13–15 May 1986
Birmingham Metropole Hotel, Birmingham

Secure Communication Systems
28–29 October 1986
London

Online, Pinner Green House, Ash Hill Drive, Pinner, Middlesex HA5 2AE.
Telephone: 01–868 4466.

Value Added and Data Network Services
4–5 March 1986
Barbican Centre, London

Open Systems Interconnection
19–21 March 1986
Tara Hotel, London

Integrated Services Digital Network
10–12 June 1986
Wembley Conference Centre, London

Statistical Workshops for Engineers

Statistics for Industry (UK) Ltd. is running a series of practical statistics courses for engineers throughout 1986. Courses include 'Introduction and Statistics for Engineers', 'Introduction to Reliability Analysis', 'Statistical Process Control', 'Statistics in Quality Assurance','Statistics in Research and Development', and 'Design of Experiments'. Details of these courses can be obtained from Miss Angela Boddy, Statistics for Industry (UK) Ltd., 14 Kirkgate, Knaresborough, North Yorkshire HG5 8AD. Tel: 0423–865955.

Telephone Poles in the British Telecom Network—A Review

Part 3—Alternative Materials

D. G. CLOW, B.A., C.ENG., F.I.MECH.E., M.I.C.E., F.R.MET.S.†

UDC 621.315.668.1 : 621.395

This article concludes a three-part review of the technology and use of telephone poles. The first two parts dealt with wood poles. Part 3 outlines the various alternatives to the wood pole that have been tried. The newest development is the hollow pole, which not only uses alternative materials but, more importantly, can be rigged without any need for the pole to be climbed by staff.*

INTRODUCTION

Although softwood has been the predominant material used for telephone poles, other materials have been used with varying degrees of success. The motivations have been various—improved appearance in the urban situation, shortage of suitable softwood, or the achievement of better durability. None of these materials proved to be a serious challenger to the softwood pole. Also, these alternative materials did not have an impact on the way the pole was used; in contrast, the more recent hollow pole completely changed the manner in which overhead construction was carried out. Since the earlier article[19] on the hollow pole was published, several developments have occurred and these are considered here.

ALTERNATIVE POLE MATERIALS—PAST EXPERIENCE

Various materials other than softwood were tried for poles, but none proved to be a serious competitor. Poles consisting of wrought-iron tubes set in cast-iron bases, aimed at giving a better-appearance installation in an urban setting, fell into disfavour when a traffic accident broke the base of one pole in a route and the loading imposed on similar adjacent poles caused the progressive collapse of the next 10 poles in the route[20].

Steel girder poles were also used when wood was in short supply during and after the First World War, and some remained in use at least until 1933.

In 1946, a field trial of galvanised sheet-steel poles was conducted[21]. These poles were made up of four tapering cylindrical galvanised thin-wall tubes. A pole was produced by inserting the bottom of one section over the top of another so that one tube overlapped the adjacent one. Shortage of suitable timber at that period led to the subsequent ordering of some 120 000 of these sheet-steel poles, but a little over a half of this quantity seems to have been supplied because of steel shortages. Few are now in service, most having succumbed to internal corrosion, which, once initiated, could seriously weaken the pole, and to corrosion on the outside, which produced unsightly rust staining.

The inability to obtain enough steel for the sheet-steel poles led to the investigation of the use of pre-stressed reinforced concrete (PRC) poles. These used less steel but were three times as heavy and two-and-a-half times as expensive as the equivalent wood pole. One thousand PRC poles were ordered, but less than half were delivered, by which time the supply of wood poles had improved and PRC poles were discontinued.

Hardwoods were also used from time-to-time, but have not proved economic. Many hardwoods are also very heavy, which makes handling more difficult, the cost of transportation from the source is high, and they tend to be difficult to screw fittings into or drill.

All these other types of pole were used in a conventional manner to the softwood pole in that they had to be climbed to gain access to wiring or cables.

FEATURES OF THE HOLLOW POLE

The novel feature of the hollow pole is the facility to do all wiring and cabling work from ground level. Climbing of poles and working aloft has long been recognised as one of the principal hazards to external telephone staff. As a result, a great deal of effort has been devoted to minimising the risks; the mandatory use of safety belts and the institution of regular pole testing are two examples of safety precautions which have led to an important reduction in fatalities and injuries. In spite of this effort, accidents still occur and, in 1972, the Experimental Changes of Practice Committee (ECOPC 1), noting the continuing number of accidents involving work on poles, requested a further review of works practices. The outcome of this review was the development of a hollow pole for use at distribution points (DPs) coupled with the invention of a method by which it could be rigged without any need to go aloft. Once the simple but ingenious method of rigging was devised and the safety problem was solved, the question was then to produce a pole that was competitive with the wood pole in whole-life costing terms.

Factors taken into an economic comparison were:

(*a*) The initial capital cost of the hollow pole is high compared with the wood pole.

(*b*) The installation of a subscriber's 'drop' is simpler and quicker with the hollow pole.

(*c*) Periodic pole examination is greatly simplified for the hollow pole.

(*d*) Timber for poles is purchased as standing trees and up to three years can elapse between purchase and use as a wood pole; the hollow pole is available immediately, and therefore capital expenditure is put quickly to use.

(*e*) The clean appearance of the hollow pole (Fig. 1(*b*) (Part 1)) is preferred by estate developers and so helps

† Local Lines Services, British Telecom Local Communications Services

* CLOW, D. G. Telephone Poles in the British Telecom Network—A Review. Part 1—Wood Poles. *Br. Telecommun. Eng.*, Oct. 1985, **4**, p. 160; Part 2—The Wood Pole as an Engineering Structure. *Br. Telecommun. Eng.*, Jan. 1986, **4**, p. 220.

to minimise the pressure for the much more expensive underground feeds to customers' premises.

(*f*) The joint between the feed cable and the dropwires can be accommodated within the body of a hollow pole.

(*g*) The hollow pole is light in weight and can easily be handled by two men when required to be erected on locations where the pole erection unit cannot gain access.

Types

Three different types of hollow pole were used (Fig. 31) in the initial large-scale field trials: a tapering glass-reinforced plastic (GRP) pole of circular cross-section, a galvanised sheet mild steel tapering pole of octagonal cross-section, and a thick-wall aluminium-sprayed mild steel pole consisting of a large parallel-sided tube at the base joined to a smaller tube for the higher section. The mild-steel poles were

Left to right: GRP, sheet steel and two-diameter steel tube types

Fig. 31—Hollow poles

expected to have a shorter life than the GRP version because of eventual corrosion, but were much cheaper than the reinforced plastic poles. However, at a later stage of development, it became feasible to consider the use of stainless-steel sheet as an alternative to mild steel for the octagonal cross-section pole, and bulk production stainless-steel poles of comparable cost to GRP poles are now being supplied. Mild-steel poles are not being purchased at the time of writing, although further work is being undertaken to improve corrosion resistance. The cost differential between mild steel poles and the other types is such that a more expensive protective system is possible within the economic constraints imposed.

MANUFACTURING METHODS

The methods which are described here are typical of those which have been used on the production of the sheet-steel and GRP hollow poles. However, there is a strong economic incentive to try to reduce costs in the case of the GRP poles, and other techniques may be developed in the future.

Sheet-Steel Poles

Sheet-steel poles are fabricated from sheets of stainless steel, 2 mm thick, in the following sequence:

(*a*) A blank of the correct shape is guillotined from the sheet.

(*b*) Door and cable entry holes are pressed out.

(*c*) The blank is then successively folded on a bending machine capable of handling long lengths until the octagonal section is completed (Fig. 32).

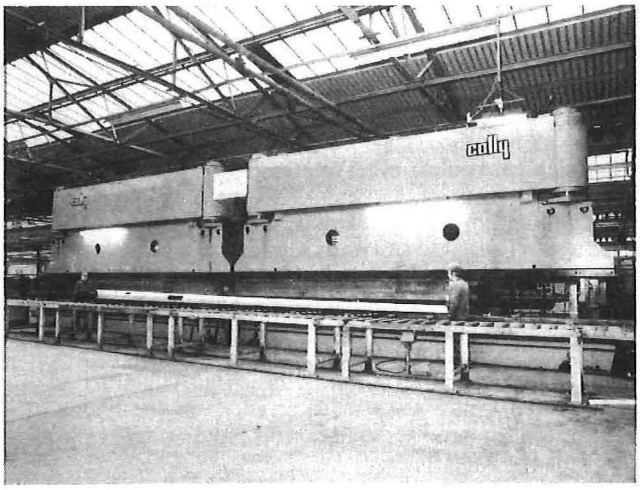


Fig. 32—Press folding a sheet-steel pole
Photograph courtesy Petitjean Co. Ltd.

(*d*) The two long edges now butt together and are fused by electric arc welding. This operation is the most difficult of the sequence as the sheet is thin; the welding procedure has to be carefully designed, otherwise the corrosion-resistant properties of the stainless steel can be impaired in the zone affected by the heat input from the welding arc.

(*e*) Finally, the door bar and the cable termination are fitted.

The mushroom-shaped pole cap is dough-moulded from GRP and fitted immediately prior to pole erection.

GRP Poles

The simple dough-moulding techniques often employed for GRP products are inappropriate for a pole. The requirement for high bending strength necessitates the use of continuous fibres of glass running the length of the pole and parallel to its axis. The fibres provide the strength, and the resin keeps the fibres in the correct position. A typical production process is as follows:

(*a*) Glass fibres are laid up on a tapered steel mandrel, which is then placed horizontally in a long centrifuge (Fig. 33). The mandrel is then withdrawn leaving the glass in the centrifuge.

(*b*) The centrifuge is spun at high speed and this throws the glass fibres outward towards the centrifuge wall, the dimensions of which determine the outside shape of the pole.

(*c*) The resin, which at this stage is very fluid, is injected into the centrifuge. The centrifuge is then tilted slightly to ensure a final uniform wall thickness; otherwise, the taper

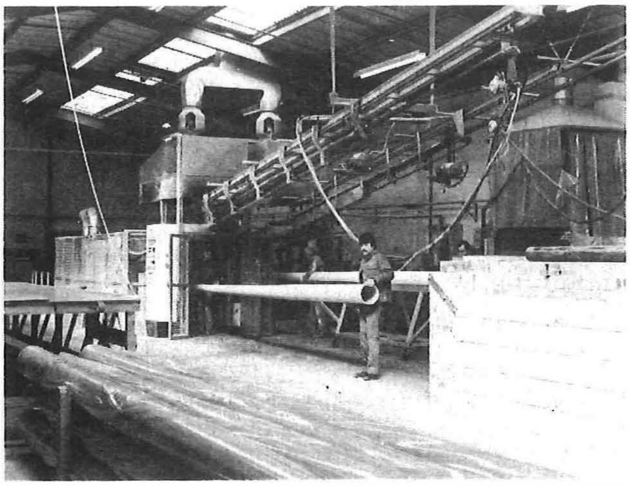


Fig. 33—Manufacturing plant for GRP poles
Photograph courtesy Laminated Profiles Ltd.

would cause the resin to flow to one end. The wall thickness varies according to the source of supply, but 12 mm is typical.

(*d*) The resin is initially cured in the centrifuge. The pole is then removed and further cured in an oven for a longer period.

A problem with the manufacture of GRP poles is that it is difficult to produce poles in a variety of lengths and strengths because retooling is necessary to produce different geometries. Only two types are presently available, 8·5 m light and 9·5 m light.

To produce a cost-competitive GRP pole calls for ingenuity on the part of the manufacturer. The most costly element is the glass fibre, and minimising the quantity needed while meeting the strength and deflection specification is particularly important. The capital cost of the manufacturing plant is high, so long production runs are needed to amortise plant and tooling costs.

An advantage of GRP is that colouring agents are readily incorporated in the resin. The normal colour is light grey, but a dark-brown version is available where environmental planning preferences prevail.

Steel Two-Section Parallel-Tube Pole

The two-section parallel-tube pole has the end of the large base-section tube swaged down to a parallel length which can be pressed into the end of the smaller diameter tube. A weld run is applied to the junction of the tubes for cosmetic reasons to give a smooth outline. The finished pole is then aluminium coated by spraying molten aluminium onto the exterior of the pole. The first batches of poles manufactured in this way had a bitumastic coating on the inside of the tubes, but an improved finish using epoxy paints is being tried to give a smoother and more durable finish.

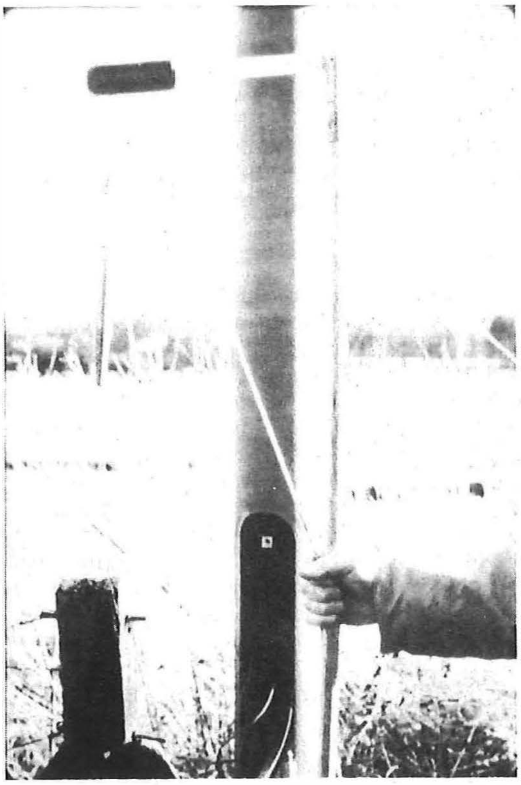
INSTALLING DROPWIRES

A simple method is adopted for wiring with hollow poles which completely obviates the need to climb the pole. The main components needed are plastic rods customarily used for rodding ducts, with a special rigging head fitted to the end of the rod. The sequence of operations is briefly:

(*a*) A sashline with a weight at one end is threaded through the rigging head as shown in Fig. 34(*a*).

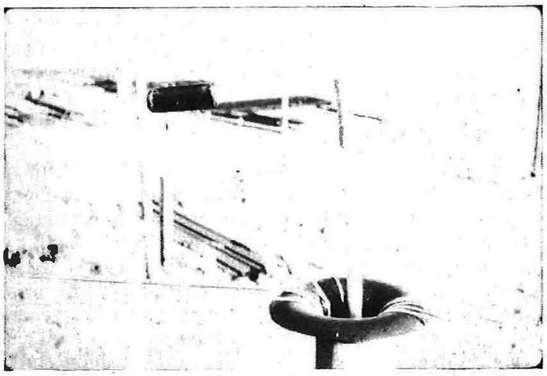
(*b*) The head is hinged and, when aligned with the rods (Fig. 34(*b*)), it can be pushed up the inside of the pole.

(*c*) When the head clears the top of the pole-cap it falls to a position at right angles to the rods, leaving the rigging weight clear of the pole (Fig. 34(*c*)).



(*a*) Rigging head with sashline and weight

(*b*) Rigging head aligned with rods



(*c*) Rigging head ready to descend outside of pole

Fig. 34—Rigging the hollow pole

(*d*) Releasing the tension on the sashline allows the weight to descend to the ground.

(*e*) The rods and rigging head are removed from the pole, and the sashline is left passing up the inside of the pole and back down to the ground on the outside.

(*f*) The dropwire can then be attached to one end of the sashline and, by pulling on the other, the dropwire can be pulled into the pole and terminated.

FUTURE DEVELOPMENTS

The concept of the hollow pole is being extended. For example, with the expansion of local broadband systems, the hollow pole has the attraction of being able to accommodate some electronic equipment within the pole itself and so removes the need for a separate housing. Methods for utilising the hollow pole to support aerial cables have been devised, but the safety and economic justifications for their use in this application are less demanding. The wood pole will be in use in large numbers for the foreseeable future; the main change here is likely to be a widening of the number of species purchased. The most useful development would be an alternative to the hammer test for detecting internal decay in wood poles, but this has so far proved to be an intractable problem.

ACKNOWLEDGEMENTS

The author is grateful for the clarification of many points by members of the Overhead Group in the External Plant Division of British Telecom (BT) Local Communications Services Headquarters (LCSHQ) and the staff responsible for procuring poles in the Materials Department.

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For Further Reading

Up-to-date documentation on pole technology is virtually non-existent. The most comprehensive treatment was an Institution of Post Office Electrical Engineers Printed Paper by Brent[10] written half a century ago. Wood decay is covered by Gerry[4] (1947). Other articles of historical value are Gibbon[22] (1910) and Morgan[23] (1916). An excellent up-to-date text on timber technology is the work by Desch[24], which has gone through several editions and has been revised recently by Dinwoodie. A short book on the biology of tree growth is by Morey[25] and a monograph produced by the Forest Products Research Laboratory[26] on Scots Pine is a useful introduction to the use of that species of tree.

Biography

Don Clow joined the Post Office in 1948 as a Draughtsman-in-Training. He became an Assistant Engineer in 1957 and was engaged in the design and provision of antennas and external equipment for high-power high-frequency transmitting stations. In 1969, he moved to his present division as Head of the Structural Engineering Group involved in design and consultancy work for masts, towers and satellite earth station antennas. He is currently Head of the Civil and Mechanical Engineering Section in the External Plant Division of LCSHQ and is responsible for civil-engineering plant and practices, cabling equipment and practices, cable pressurisation and general mechanical aids and tools. He is also the BT representative on the Executive Committee of the National Joint Utilities Group (NJUG). He has an honours degree from the Open University and specialised in geology and materials technology.

Book Review

Foundations of Wireless and Electronics. Tenth Edition. M. G. Scroggie. Butterworth Group. 551 pp. 383 ills. £8·95.

This is the tenth edition of Mr. Scroggies's useful basic textbook on radio and electronics. The emphasis is predominantly 'analogue' (to use today's classification), but that renders the book none the less useful, as digital techniques are catered for elsewhere. Most of the book is concentrated on radiocommunication pure and simple, with small sections on computers and radar.

There are 27 chapters. The author commences with the basics of a radio communication system, then proceeds to electrical theory, active devices and their use in radio. It was particularly pleasing to see a section on radiation and antennas, as this tends to be omitted in training courses and yet is crucial to the whole art of radio. Sections are included on transmission lines, non-sinusoidal signal amplification, electronic waveform generators and switches, computers and power supplies.

The chapter on transistors deals in considerable detail with design parameters, and this might be more useful for students of a formal course than those requiring practical information. On the other hand, the operational-amplifier integrated circuit receives a fairly short description, as do printed circuits.

Earlier editions of this book used various expressions as *a.v.* (alternating voltage), *d.v.* (direct voltage), and *z.f.* (zero frequency). While very correct, these terms are not in common use and we were therefore pleased to see that they had been dropped. However, the term *sender* for a radio transmitter is still used in the text; perhaps this is not helpful to beginners entering this field as the term is not commonly used.

In general, the book will be useful to anyone starting studies in radio or electronics, and might be of some value to those versed in, say, digital electronics but not radiocommunications.

Although only an introduction to the subject, the basic knowledge down to component level, together with an appreciation of radio-frequency techniques, is an essential yet often missing attribute for engineers involved with telecommunications.

Mr. Scroggies's name has, we think, figured on reference books used in our office for about 40 years, and will no doubt continue to do so in the future—no mean feat when one considers that technology has changed so rapidly.

D. J. SUMNER, and F. D. GALLIANO

The Eleventh International Teletraffic Congress, Kyoto, 1985

D. J. SONGHURST, B.SC.,M.SC.†

The Eleventh International Teletraffic Congress (ITC) was held in Kyoto, Japan, from 4–11 September 1985, under the sponsorship of the Japanese telecommunications organisations. This triennial conference is a forum for the publication of new work in the field of teletraffic theory and its application in engineering, operations and planning related to telecommunications and computer systems. The Eleventh ITC carried the specific theme of 'teletraffic issues in advanced information society'.

The Congress was attended by nearly 400 delegates from a wide range of countries. The UK delegation of seven was a particularly small one on this occasion, and included few representatives from manufacturing industries and none from universities. The three UK papers all emanated from the British Telecom (BT) Performance Engineering (previously Teletraffic) Division.

The proceedings of the Congress contain 170 technical papers covering a very broad range of subject matter, ranging from traffic theory, queueing theory and simulation methodology, to their applications in telephony and data networks and switching systems, satellite and mobile radio systems and integrated services networks. One subject that received inadequate coverage was computer performance—this material had largely been diverted to the Seminar on Computer Networking and Performance Evaluation held in Tokyo on 18–20 September.

An area of major activity is that of telephone network analysis, optimisation and routeing strategies. Here the interest is shifting away from the standard hierarchical structure with alternative routeing towards non-hierarchical networks and dynamic-routeing strategies. On this front, the American Telephone and Telegraph Company (AT & T) is well advanced in terms of implementation, although less so in terms of supporting theoretical study. France is particularly strong in this field, and a French contribution presents one of the first objective and comparative studies of a range of different dynamic routeing policies.

Traffic administration, measurement and forecasting is another active field of study; notably, work is continuing on sophisticated time-series methods for forecasting. Little of this work has significant novelty, however. Traffic modelling is developing steadily, through improved models for telephone traffic variability, and through new information on the characteristics of other types of traffic, including data and facsimile.

Mobile radio systems are being increasingly studied, and this work attracted considerable interest. Gradual progress is being made with the difficult problems of dynamic channel allocation, and a range of other problems, such as the behaviour of handover, is also being given increasing attention.

Performance evaluation of processor-controlled exchange systems is an important field. Whereas BT teletraffic work in this area is largely via the use of computer simulation, many papers at this Congress (in particular from Germany and Japan) explored the application of queueing theory, with substantial involvement from academic institutions. While this work is no doubt of use for its intended applications, these do tend to be rather specialised. There was considerable uncertainty about the effects of new services on the performance of processor-controlled systems.

Several papers on local area networks (LANs) were presented. Two particularly interesting contributions concerned a technique for controlling the spread of overload in a network of LANs, and a statistical breakdown of the traffic on a large LAN. Disappointingly, there was virtually no representation from the computer industry, and thus, despite its theme, the Congress failed to give proper coverage to information technology issues.

The competitive environment in the USA is clearly making itself felt, both in the reduction in papers describing AT & T administrative procedures, and in the appearance of papers specifically addressing issues relating to competition. As yet, there is nothing from the UK on this front.

Overall, it seems that BT is doing well in studies of quality of service, some aspects of network modelling and routeing, and the simulation modelling of exchange systems and local area networks, although our work is less well publicised than some others. BT is lagging in the development of queueing theory for processor-system studies, and has a very low international profile with regard to traffic studies of new services and the integrated services digital network.

The Twelfth ITC will be held in Turin, Italy in June 1988.

† Research Department, British Telecom Development and Procurement

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(Founded as the Institution of Post Office Electrical Engineers in 1906)

General Secretary: Mr. J. Bateman, National Networks Strategy Unit (NNSU1.4), Room 304, Williams National House, 11–13 Holborn Viaduct, London EC1A 2AT; Telephone: 01–357 3918.
(Membership and other enquiries should be directed to the appropriate Local-Centre Secretary as listed on p. 177 of the October 1985 issue.)

IBTE LOCAL-CENTRE PROGRAMMES

Unless otherwise stated, members must obtain prior permission from the Local-Centre Secretary to bring guests.

Aberdeen Centre

Members will be advised individually of locations for meetings. All meetings commence at 14.00 hours.

18 February 1986:

Cellular Radio by Mr. B. McPhee, Marketing Manager, Cellnet.

11 March 1986:

AXE 10 (System Y) by Mr. D. Colbeck, Thorn Ericsson.

Anglian Coastal Centre

Meetings will be held in Room LTB5, University of Essex, commencing at 14.00 hours, unless otherwise stated.

Wednesday 12 February 1986:

Network Nine Concept by Mr. D. J. Brunnen, Business Manager, Network Nine. Meeting to be held in the Assembly Rooms, Norwich at 14.00 hours.

Wednesday 12 March 1986:

Optical Character Recognition by Mr. H. A. J. Bennett, OCR Project Manager, The Post Office.

Wednesday 23 April 1986:

Marketing in British Telecom by Mr. N. J. A. Kane, Director of Marketing, British Telecom. Meeting at Guildhall, Cambridge, commencing at 14.00 hours.

Wednesday 21 May 1986:

The Role of British Telconsult by R. Marchant, Marketing Manager, Middle and Far East.

Bletchley/South Midlands Centre

All meetings will be held at Bletchley Park and will commence at 14.15 hours, except where stated otherwise.

Wednesday 26 February 1986:

Submarine Cables by Dr. T. R. Rowbotham, British Telecom Research Laboratories.

Wednesday 23 April 1986:

Marketing in British Telecom by Mr. N. J. A. Kane, Director of

Standing (left to right): B. House, R. Cox, B. Farr (Secretary/Treasurer, *Journal*), J. Bateman (Secretary), R. K. Drinkwater, J. H. Inchley (Assistant Secretary), D. Bull, D. Norman, C. Stanger, R. E. Burt
Seated (left to right): J. Tippler (President, Associate Section), A. B. Wherry (Vice Chairman), J. F. Boag (Chairman), A. Beardmore (Vice Chairman), R. New (Honary Treasurer)
Not present: K. Chinner, G. A. Gallagher, H. Goodison, K. Moore

The Council of the Institution pictured at its recent meeting at Martlesham Heath

Marketing, British Telecom. Meeting at Guildhall, Cambridge, commencing at 14.00 hours.

Central Midlands

Meetings will be held in the Lecture Theatre, Room UG35, British Telecom, Berkley House, commencing at 14.00 hours, except where stated otherwise.

Thursday 13 February 1986:

Integrated Circuit Technology and Failure Causes by Mr. R. G. Taylor, Materials and Components Centre, British Telecom Development and Procurement. Meeting will be held in the Conference Room, 310 Bordesley Green, Birmingham, with laboratory demonstration, and will commence at 14.00 hours.

Thursday 13 March 1986:

High Definition Television by Mr. D. P. Laggatt, Chief Engineer, External Relations, British Broadcasting Corporation.

Thursday 10 April 1986:

JET (Joint European Torus) Project by Dr. E. Bertolini, Head of Power Supply Division, JET Joint Undertaking.

East Midlands

All meetings will commence at 14.00 hours.

Wednesday 5 February 1986:

Making Technology make a Profit by Mr. R. Farrow, British Telecom Local Communications Services. Meeting will be held at Nottingham University.

Wednesday 5 March 1986:

Remote Line Testing by Mr. A. Hart, Northern Telecom (UK) Ltd. Meeting will be held at Leicester University.

Wednesday 9 April 1986:

The Changing Role of the Engineer in British Telecom by Mr. J. W. Young, Territorial Engineer, British Telecom. Meeting will be held at Peterborough Technical College.

Martlesham Heath

Meetings will be held in the John Bray Lecture Theatre at the British Telecom Research Laboratories, Martlesham Heath, and will commence at 16.00 hours.

Wednesday 19 February 1986:

Marrying R & D to BT's Commercial Needs by Dr. P. Troughton, Managing Director, British Telecom Enterprises.

Tuesday 11 March 1986:

The Wireless Society: Does it Lack Moral Fibre? by Dr. J. E. Thompson, Deputy Director Research Department and British Telecom's Chief Professional Radio Engineer.

Thursday 3 April 1986:

BTAT: Building IT Systems for BT's Customers by Mr. G. G. Brooks, Chief Executive, Applied Technology, British Telecom Enterprises.

Wednesday 23 April 1986:

Hardware Techniques for the 90's by Dr. B. A. Boxall, Switching Technology Division, British Telecom Research Laboratories.

Mid Anglia Centre

All meetings commence at 14.00 hours.

Wednesday 12 February 1986:

Electronic Funds Transfer by Mr. B. D. Hingston, British Telecom National Networks. Meeting will be held at the Exservicemen's Club, Peterborough.

Wednesday 12 March 1986:

Managing National Networks by Mr. R. E. G. Back, Corporate Director, Managing Director British Telecom National Networks. Meeting will be held in Rhodes Centre, Bishop's Stortford.

Wednesday 9 April 1986:

The Changing Role of the Engineer in British Telecom by Mr. J. W. Young, Territorial Engineer, British Telecom. Meeting will be held in Peterborough Technical College.

Wednesday 23 April 1986:

Marketing in British Telecom by Mr. N. J. A. Kane, Director of Marketing, British Telecom. Meeting at Guildhall, Cambridge.

North Downs and Weald

Wednesday April 30 1986:

National Networks by Mr. R. E. G. Back, Corporate Director, Managing Director British Telecom National Networks. Meeting will be held at the Great Danes Hotel and will commence at 14.15 hours.

Scotland East Centre (Edinburgh)

Members will be advised individually of locations for meetings. All meetings commence at 14.00 hours.

19 February 1986:

Why Forecast the Weather? by Mr. J. Allardice, Glasgow Weather Centre.

19 March 1986:

Optical Fibre Cable by Mr. D. Stanley and Mr. J. Macauley, British Telecom National Networks.

Scotland East Centre (Dundee Sub-Centre)

Members will be advised individually of locations for meetings. All meetings commence at 14.00 hours.

12 March 1986:

AXE 10 (System Y) by Mr. D. Colbeck, Thorn Ericsson.

Scotland West Centre

Members will be advised individually of locations for meetings. All meetings commence at 14.00 hours.

20 February 1986:

Electrostatics Seminar by Mr. D. Ray, Materials and Components Centre, British Telecom Development and Procurement.

20 March 1986:

Optical Fibre Cable by Mr. D. Stanley and Mr. J. Macauley, British Telecom National Networks.

Severnside Centre

Meetings will be held in Nova House, Bristol, commencing at 14.15 hours, except where stated otherwise. Members must obtain prior permission from the Local-Centre Secretary to bring guests.

Wednesday 5 February 1986:

Quality in a Service Industry by Mr. P. Gillam, Major Systems Procurement, British Telecom Development and Procurement. Details of venue not available.

Wednesday 2 April 1986:

LCS in the New Environment by Mr. I. D. T. Vallance, Corporate Director, Chief of Operations, British Telecom. Meeting will be held at Queens Buildings, University of Bristol.

British Telecom Press Notices

Joint Venture for Electronic Business Transactions

A new high-technology company, which aims to reduce the cost of business transactions, has been formed by British Telecommunications plc and McDonnell Douglas Information Systems Ltd. The new venture, called *Edinet Ltd.*, provides and markets the range of information technology services known as *electronic data interchange* (EDI). EDI provides direct computer-to-computer exchange of business documents such as purchase orders, invoices and statements. These are sent in electronic form in such a way as to reconcile differences in computers and document formats. As well as achieving major savings in business transactions, EDI can help companies to cut their inventory and stock-holding costs.

Edinet Ltd., equally owned by its two parent companies, offers EDI services and is developing software products for the EDI market. When this type of value-added service is used, the cost of creating, processing and transmitting such documents is literally cut from pounds to pence.

According to the independent Yankee Group consultancy, the McDonnell Douglas Electronic Data Interchange Company is the market leader in the USA, and is used there by more than 200 companies, including Hewlett-Packard, Dow Chemical, and Super Valu Stores, for purchase orders, invoices and shipping documents.

Edinet Ltd. has already begun marketing its services in the UK. Initially, it will rely on processing resources based in the USA. Customers will be connected to them through British Telecom's (BT's) Packet SwitchStream public data service. The services conform to the internationally-accepted open standards for document interchange as developed by the United Nations Organisation. The joint venture company will assist its customers to adopt these standards whenever possible.

This new company has been launched to meet the widespread demands from customers that BT has received for an EDI service. It will bring the economic benefits of automated electronic transactions to many businesses, large and small, and will cut their overheads and sharpen their competitive edge.

The new company combines the experience and services of BT in telecommunications with the expertise of McDonnell Douglas as the EDI market leader in the USA. It is set to realise some of the enormous potential for growth in this market in the UK and Europe. In the future, BT and McDonnell Douglas plan to exploit opportunities for joint development in the USA market.

In addition, it will enable BT to establish a new strategic direction in the evolution of its business towards its goal of a world-wide information technology company. This could lead to expansion not only in the UK, but also in overseas markets, in particular those of North America.

Interest in more cost-effective ways of exchanging essential business documents is growing fast and, although the market is still embryonic, Edinet Ltd. has great potential as part of a world-wide network of electronic interchange services. It is hoped that Edinet will have built up a significant market in the UK by 1990.

New Optical-Fibre Record Set to Cut Costs

A new world record for optical-fibre transmission set by British Telecom (BT) promises to help contain the cost of expanding the network. A team of engineers from BT Research Laboratories, National Networks and the Central Midlands District has succeeded in transmitting data over 32 km of single-mode fibre at a rate of 2·6 Gbit/s, the fastest rate yet achieved over an installed cable.

Unlike previous laboratory demonstrations, this feat was achieved over an existing cable, linking Birmingham with Tamworth. It illustrates the feasibility of upgrading existing optical systems without the need to replace cables. Considerable sums could be saved in the future by providing only new terminal electronics to expand the capacity of cables rather than by replacing complete systems.

The data rate achieved represents a 16-fold increase in capacity over the existing 140 Mbit/s systems and is equivalent to passing 30 720 separate speech channels or 32 full-bandwidth colour television pictures down the same single optical fibre.

The key factor to this achievement was the use of a ridge-waveguide distributed-feedback (DFB) laser, made in BT's research laboratories. It gives an absolutely pure single-wavelength output at 1·52 μm, which is necessary to avoid the distortion that would occur with less-pure multi-wavelength signal sources in this application. The wavelength, longer than that used by current fibre systems (1·3 μm), was chosen because of the significantly lower losses (and hence further transmission) at this frequency.

Growth in the Use of Prestel

Use of Prestel, British Telecom's (BT's) public viewdata service, has grown by 44% in the past year, with more than one million pages a day being accessed and more than 100 000 electronic mail messages a week.

This was revealed by David Musson, Prestel's head of marketing, at an international conference in Amsterdam in what the conference organisers described as 'the frankest ever analysis by a public national videotex operator'. Mr. Musson ascribed Prestel's success to a strategy of developing specific products for specific target markets. For the past three years or so, Prestel has been pursuing its product research and development to market-place needs, and a key measure of its success lies in the fact that some 75% of all new registrations in that period have been triggered by product initiatives.

Specific areas that have attracted new users to Prestel include travel, insurance, microcomputing, City information, farming information, home banking and shopping, and messaging, messaging now includes full outgoing and incoming Telex facilities.

The introduction of specialist 'welcome' frames, improved indexing and special features have all contributed to Prestel's growth. Successful packaging and indexing of the information from the travel trade, where in 1985 it was estimated that 50% of package holidays were booked within four weeks of departure, saw use grow from 2000 accesses a week in August 1984 to 15 000 a week in August 1985.

When a Teleshopping service was launched, it was made the special feature on the first and third days of the service. On each day, some 3000 enquiries were generated.

Prestel's product-based marketing approach has produced a four-fold increase in revenue, while operational improvements have reduced expenditure by 40%. Prestel is now trading at a profit on its own account, not including the substantial revenue it generates through telephone calls. With a steadily increasing customer base and greater usage, the future for Prestel looks healthy.

British Telecom Taxiphone

British Telecom (BT) was the first to launch telephones in London taxis; a pilot scheme was introduced towards the end of last year in which some 50 cabs were fitted with taxiphones in their passenger compartments.

The scheme is based around a standard BT Cellphone with a charging mechanism attached, and operates for outgoing calls only. Calls are paid for at the same time as the fare. A special telephone meter enables the cab driver to see the call charge separately from the taxi fare, and allows statistics about the use of the telephone to be recalled; that is, the total money taken to date and the total number of customers. This meter also drives a special customer display which shows the taxiphone user how much a call is costing.

To make a call, the customer simply lifts the taxiphone handset, enters the desired number, including the full subscriber trunk dialling (STD) code, and then presses the flashing SND (send) key. After a while, the PAY indicator flashes and the loudspeaker is activated. When the call is answered, as heard through the loudspeaker, the customers presses the PAY button, which connects the handset audio and enables charging. When the conversation has finished, the user presses the END key to stop the telephone meter. The user can then either make follow-on calls in exactly the same way, or return the handset to its rest.

The BT taxiphone can be used only when the cab's engine has been started. All the cab driver has to do is reset the equipment after each passenger, which is done simply by pressing the RESET button on the telephone meter.

All taxiphones incorporate a 'credit lock' mechanism to minimise the financial risk through non-payment of potentially large bills. A code within the Cellphone prevents use after a certain amount of charges have accumulated. However, a driver cannot terminate a passenger's call, even if the credit lock comes into operation.

Cab drivers are billed for calls made from BT taxiphones as if they were standard BT Cellnet customers, and pay the Cellnet subscription in exactly the same way as other cellular users.

British Telecom taxiphone

Software Package for Elections

A unique software package to computerise election administration has been introduced by West Wiltshire District Council and British Telecom (BT). The package, known as the *Election Administration System*, deals with all the legal, administrative and financial requirements of an election, acts as an *aide-memoire* to ensure that all tasks are completed and produces every piece of documentation. It can handle any type of election—Parliamentary, European, county, district or parish—and, if necessary, more than one at a time. The package is being provided jointly by BT Applied Technology (BTAT), part of BT Enterprises, and West Wiltshire Software (WWS), a division of West Wiltshire District Council.

Elections of all types are the biggest recurrent administrative problem any local government officer has to face, particularly as complex election law has to be observed with perfect accuracy. The new system is the first modern method of dealing with Britain's traditional democratic processes. Returning officers in local authorities have to administer all types of election—from Parliamentary to parish—in strict accordance with specified timetables and legislative requirements. Any mistake or omission can invalidate the whole procedure. An election for district and parish councillors in a typical local authority area might involve nearly 1000 candidates from 30 district wards and 40 parish councils; more than 4000 election, counting and polling agents; and 500 staff ranging from presiding officers to counting assistants. The total number of unique documents, forms and notices required could easily exceed 25 000.

On the new system, a master diary starts 60 days before polling day and displays each step throughout the election, every step having its own critical time path. After the initial entry of data such as names, addresses and timings, all subsequent documentation is accurately produced and personalised at the touch of a button. No entry on the master diary can be removed before all necessary stages have been completed and confirmed. In this way, the system guides the returning officer through all the paperwork and legal intricacies which characterise every stage of the election process. The Election Administration System is consistent with all existing election legislation; BTAT and WWS guarantee to update the system in line with any future changes. The software is available for both ICL and IBM computers.

New Telephone Service Centre for Hull

One of the first operations and maintenance centres (OMCs) to be commissioned in Britain was handed over by British Telecom (BT) to the independent Hull Telephone Department in November last year. The equipment, which was designed and installed by BT, will be used to control three System X exchange units, and will provide centralised maintenance and administration control for up to 300 000 telephone lines.

BT won the Hull contract in competition with industry. The same BT-made OMCs are currently being introduced in System X exchanges elsewhere in Britain as part of a national programme by BT: a total of around 100 will be built up within a few years.

The new OMC will enable the Hull Telephone Department to connect new customers and clear faults with the minimum of delay. The OMC makes this possible by adding remote control and centralised maintenance facilities to the computerised System X exchanges. Action, for instance to bring into service a new line or to clear a fault, can be taken from a distance by local technical staff using a keyboard and visual display unit, without having to visit the equipment. All instructions are entered through the terminal and are interpreted by software control. A single command from this terminal is translated automatically into a series of, typically, 50 instructions to the System X exchange.

The OMCs were designed by BT's Technology Executive at Ipswich. The software runs on proprietary computer equipment, and the system uses specialist alarm-handlinq hardware manufactured by BT Fulcrum's factory in Birmingham.

Notes and Comments

JANUARY 1985 SPECIAL SYSTEM X ISSUE

The editors regret that the January 1985 special issue of the *Journal* on System X is now out of stock.

CORRECTION

The book review by P. G. Wilson on p. 128 of the October 1985 issue of the *Journal* gives the wrong book title. The text of the review in fact refers to *Introduction to Microwaves* by R. E. Gardiol, and published by Artech House Inc. at £37·00.

CONTRIBUTIONS TO THE JOURNAL

Contributions of articles to *British Telecommunications Engineering* are always welcome. Anyone who feels that he or she could contribute an article (either short or long) of technical, managerial or general interest to engineers in British Telecom and the Post Office is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article if needed.

Educational Papers

The Editors would like to hear from anyone who feels that they could contribute further papers in the series of educational papers that is to be published in the *Supplement* (for example, *Microcomputer Systems Parts 1 and 2*, October 1984 and January 1985 issues). Papers could be revisions of British Telecom's series of *Educational Pamphlets* or, indeed, they could be completely new papers. It is intended that they would deal with telecommunications-related topics at a more basic level than would normally be covered by articles in the *Journal*. They would deal with, for example, established systems and technologies, and would therefore be of particular interest to those who are new to the telecommunications field, and would be useful for revision and reference and for finding out about new topics.

In the first instance, intending authors should write to the Deputy Managing Editor, at the address given below, giving a brief synopsis of the material that they would like to prepare. An honorarium will be paid for suitable papers.

EDITORIAL OFFICE

All correspondence relating to editorial matters ('letters to the editor', submissions of articles and educational papers, requests for authors' notes etc.) should be sent to the Managing Editor or Deputy Managing Editor, as appropriate, at the following address: *British Telecommunications Engineering*, NN/CMkt2.2, Room 107, Intel House, 24 Southwark Bridge Road, London SE1 9HJ. (Telephone: 01–928 8286 Extn. 2233.)

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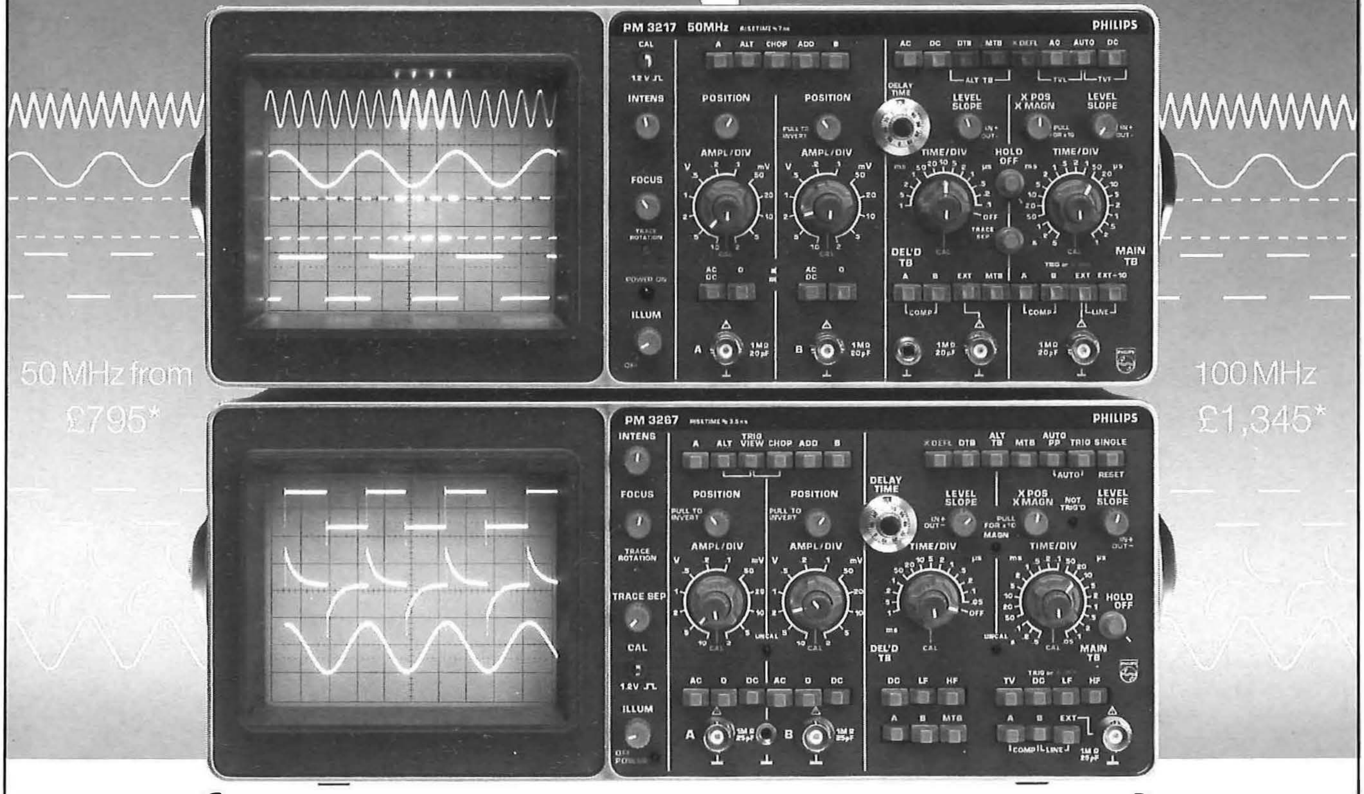

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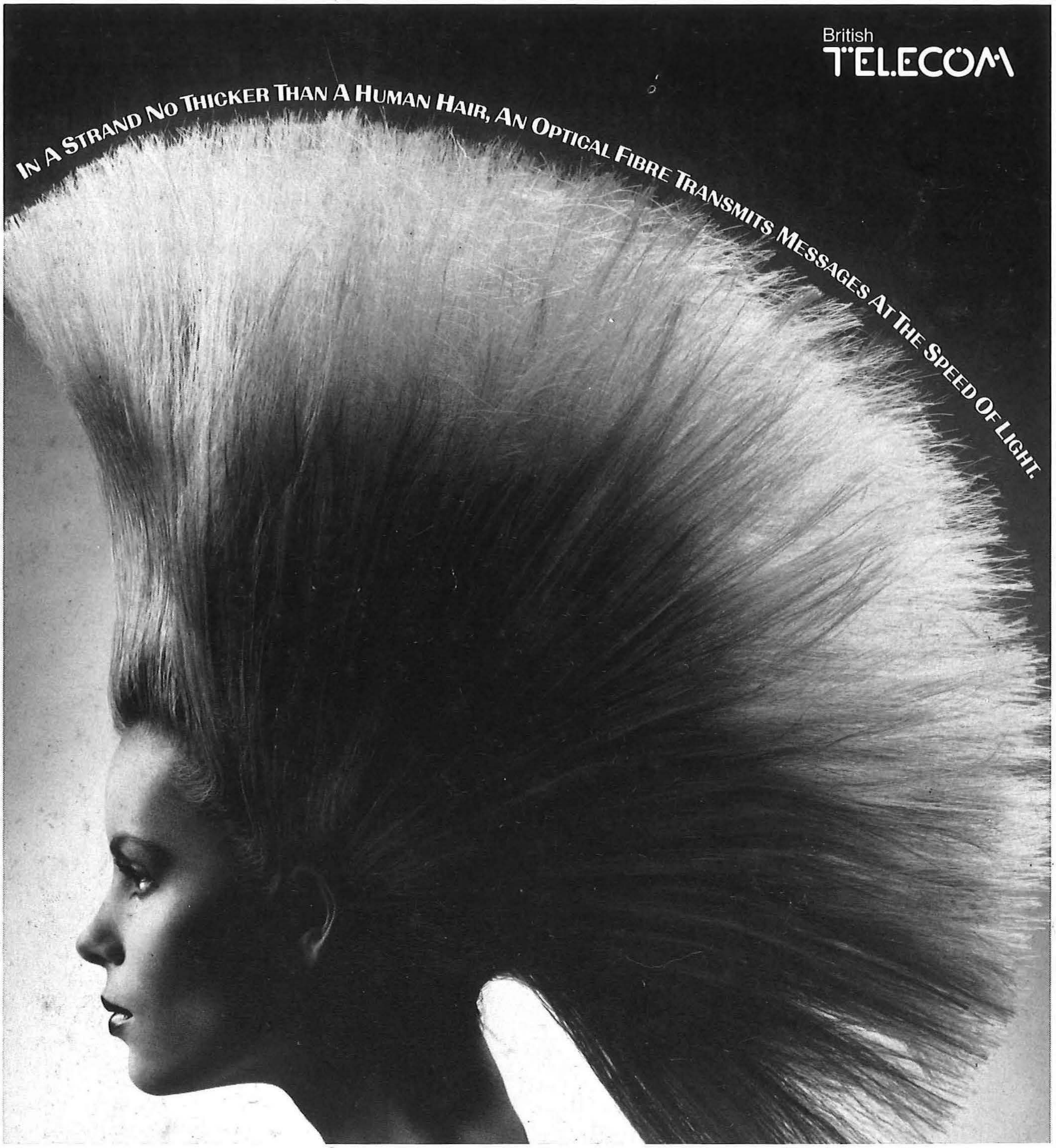

STARTLING, ISN'T IT?

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