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# UXD5: A Small Digital-Switching Telephone Exchange for Rural Communities

## Part 1—General Description

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*The UXD5 is a high-technology, digital-switching telephone exchange designed for use in rural areas where telephone penetration is small. The design of the UXD5 is based on the Monarch 120 PABX<sup>1</sup> and is intended as a replacement for Strowger Unit Automatic Exchanges at present installed in the UK telephone network. This part of the article gives a general description of the UXD5 design and its application; Part 2 will describe the system software and operational aspects.*

### INTRODUCTION

Rural areas have always presented particular problems for telephone operating administrations. Scattered communities with low telephone penetration, often coupled with adverse terrain, lead to difficulty in offering an economic and reliable service. In the early days of the UK telephone network, service was provided by small manual boards, usually sited at the local Post Office. During the 1930s it became apparent that these manual boards were becoming increasingly uneconomic, therefore the British Post Office (BPO) introduced a family of small Strowger exchanges to cater for the needs of small rural communities. These exchanges, designated *Unit Automatic Exchanges* (UAXs), were constructed from a series of standard cabinets housed in standard buildings. The standard design of these exchanges led to low installation costs and high reliability, and these exchanges offered to the rural subscriber a service comparable with that available in towns and cities.

UAXs still form a large part of the BPO network in rural areas, having been modified for trunk dialling from 1969. There are over 2000 exchanges in the UK network with less than 400 lines, a high proportion of which are of the UAX type. Scotland has a particularly large number of small exchanges, over 600 of which have less than 200 lines. Many of these small exchanges are now over 40 years old and are reaching the end of their service lives.

Modernization of the BPO network is based on the System X family of exchanges: it is the intention of the BPO to replace all Strowger exchanges by the turn of the century. Initial development of the modernization programme has necessarily been concentrated on the larger exchanges and, therefore, an interim programme is required for the replacement of UAXs; in particular, the replacement of UAX12s. The cost of developing a new small exchange would be very high, and low equipment quantities would lead to high production costs. These costs have, however, been reduced substantially by adopting a new exchange design based on an existing system which is scheduled for bulk production; that is, the Monarch 120 PABX<sup>1</sup>, which can be adapted with minimum design change to fulfil the operating requirements of a UAX12.

In early-1978, a feasibility study indicated that modification of the Monarch 120 system to provide the facilities of a UAX12 would be possible, and recommended that a model

be built for trial in the public telephone network. A feasibility trial model entered service at Glenkindie, near Aberdeen, on the 31 July 1979. The trial has been successful, and production of the system, known as *Unit Exchange Digital No. 5* (UXD5), is scheduled to commence in 1981.

### BACKGROUND TO THE DEVELOPMENT OF THE UXD5

The UAX12 is the smallest of the unit Strowger exchanges still in use; there are over 200 in service, mostly situated in Scotland. Initially, the UAX12 was designed to cater for 100 terminations (subscribers plus junctions), but later development permitted extension to 160 subscribers. Switching is centred on pre-2000 selectors, which act as group selectors for junction calls and as final selectors for terminating calls.

The basic UAX12 exchange is housed in three types of standard unit, designated *A*, *B* and *C*. The *A* and *B* units contain line circuits, subscribers' meters, line finders and selectors; the *C* unit contains the main distribution frame (MDF) and common equipment. Other units, housing junction and coin-and-fee checking relay-sets, have been added to provide trunk dialling facilities. Junctions carry mixed level 1, 9 and 0 traffic; a discriminating digit is used to segregate ordinary and coin-collecting box (CCB) level 0 traffic at the group switching centre (GSC). A typical exchange of 90 lines comprises a suite of racks approximately 4 m long and 1.8 m high.

Investigation into possible methods of replacing the ageing UAX12 installations included the possibility of using concentrators or network amalgamation. However, it became apparent that the cost involved in changing the established network in remote areas would be substantial. Therefore, the BPO decided to develop a replacement system based on the design of the Monarch 120 PABX.

The Monarch 120 system is the new standard rental-range PABX which has been developed by the BPO in conjunction with UK telecommunications manufacturers. The system caters for a maximum of 120 dial or keyphone extensions, which is approximately the correct size for a UAX12 replacement. The Monarch 120 system offers many of the facilities needed on a public exchange and its microprocessor control<sup>2</sup> has an inherent flexibility, a feature that has eased the modification process.

The UXD5 feasibility trial model was developed to demonstrate that a small public exchange, based on the Monarch 120 design, could be built with minimum change to the basic

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design. The design of the UXD5 was concentrated on meeting 4 main objectives:

- (a) that the exchange would be capable of operating in the same network configuration as a UAX12;
- (b) that, for ease of installation, the system would be of unit design;
- (c) that, for ease of maintenance, the equipment would be provided with advanced diagnostic facilities; and
- (d) that the system design would be flexible to enable the provision of advanced facilities, should they be required.

### **ADAPTATION OF THE MONARCH 120 PABX AS A PUBLIC EXCHANGE**

Originally conceived as a PABX, the Monarch 120 lacks certain features normally required for the public network. The main areas that required modification were

- (a) availability performance and power supply arrangements,
- (b) call-charging facilities,
- (c) junction signalling facilities, and
- (d) operation of CCB services.

### **Availability Performance and Power Supply**

The reliability of the Monarch 120 system depends on the correct operation of the control shelf and the mains power shelf. A failure in either of these subsystems could disable the whole, or a substantial part, of the exchange. Theoretical calculations have indicated that the mean-time-between-failures (MTBF) of the exchange due to either of these causes is approximately 3.5 years, excluding failure of the mains supply. While this value of MTBF is appropriate for a small PABX in an office environment, it is not suitable for a remote unattended public exchange; a MTBF in excess of 50 years is required in this application.

For the UXD5 exchange, an increase of MTBF to approximately 100 years has been obtained by duplication of the control shelves and by introducing DC-DC converters operating from a standard -50 V supply, which removes direct reliance on the public mains supply. One control shelf acts in a standby mode and is activated on detection of a fault in the working control shelf, thereby maintaining service until the faulty control shelf is repaired. Use of the DC-DC converters allows a small area of the exchange to be powered from each converter so that, in the event of a converter failure, service to only a limited number of subscribers is affected.

### **Call Charging**

The Monarch 120 system offers a selective call-logging facility which does not meet the requirements for public network call-timing and charging. At the time of the UXD5 development the billing arrangements for System X had not been finalized, so it was therefore decided to develop the hardware and software required to operate standard subscribers' meters in the usual manner. Charging operates in exactly the same way as a UAX exchange by using local-call timing (LCT) and metering-over-junction (MOJ) pulses from the parent GSC. However, the UXD5 system has been designed so that a billing system providing System X data can be easily attached at a later date.

### **Junction Signalling**

There is no provision in the Monarch 120 system for public network signals such as MOJ, trunk offer (TKO), and manual hold because the exchange interfaces only with public exchange lines. Hardware and software have therefore been developed to interwork with existing loop disconnect (LD), SSDC2 and SSAC8 signalling systems. A circuit is being

developed which, with the aid of a single-chip microprocessor, will be able to work to a wide range of DC signalling systems, including those mentioned above.

Description of the UXD5 software and system operation will be the subject of Part 2 of this article, which will be published in the April 1981 issue of the *Journal*.

### **Operation of Coin-Collecting-Box Services**

No provision was needed in the Monarch 120 system for the control of CCBs. A self-contained CCB for use in the low-revenue areas serviced by UXD5 exchanges is not likely to be available for some time, so a special line unit has been developed to handle coin-pulse signals and to control the coin slots of existing pay-on-answer CCBs. Use of this line unit, plus additions to the exchange software, enables UXD5 exchanges to perform the standard coin-and-fee-checking process without the addition of any further hardware.

### **UXD5 SYSTEM ORGANIZATION**

A system block diagram of the UXD5 is shown in Fig. 1. To take advantage of common volume production and to minimize design work, the UXD5 design uses, wherever possible, equipment produced for the Monarch 120 system.

### **Line Shelves**

The line shelves and backplanes of the UXD5 are identical to those used in the Monarch 120 system. The line cards interface with customers' 2-wire lines and provide digital speech and signalling, at 72 kbit/s, to and from the shelf multiplexers; the signalling and speech are separated in the shelf multiplexers. A line card contains 4 subscribers' line circuits.

The MDF incorporates gas-discharge protection devices on each line to prevent lightning surge voltages being passed to the digital circuits.

The line shelves house the line units designed for use with CCB lines and junction signalling cards; receivers for multi-frequency signalling (SSMF4) telephones can also be accommodated on the line shelves. Monarch 120 multiplexers are used to multiplex the digitally encoded speech from the 32 ports on a line shelf onto a single 2.048 Mbit/s highway and to perform demultiplexing in the opposite direction of transmission. The digitally encoded signalling to and from the 32 ports on a line shelf is carried on a pair of 256 kbit/s highways, one for each direction of transmission.

The line shelves also accommodate a test line unit, which provides facilities for the automatic routine testing of the digital circuitry associated with each line and junction card, as well as much of the control shelves; the test line unit design is the same as that used for the Monarch 120 system.

### **Control Shelves**

Although the control shelves use a high proportion of Monarch 120 circuit cards, the backplane wiring has been modified to allow duplication of the control shelves to meet the availability requirements. Only one of the control shelves is active at a time; the other control shelf is operated in an idle mode, in which it executes a program that checks for faults in its own equipment. The idle shelf takes over the control of the exchange automatically should a fault be detected in the active unit.

Each control shelf includes a change-over card specially designed for the UXD5. These cards incorporate tri-state buffers which pass clock waveforms, signalling and digitally encoded speech from the operational control shelf to the ribbon cables which interconnect the line and control shelves. The change-over cards on the control shelves are interconnected in such a fashion that only one shelf can have

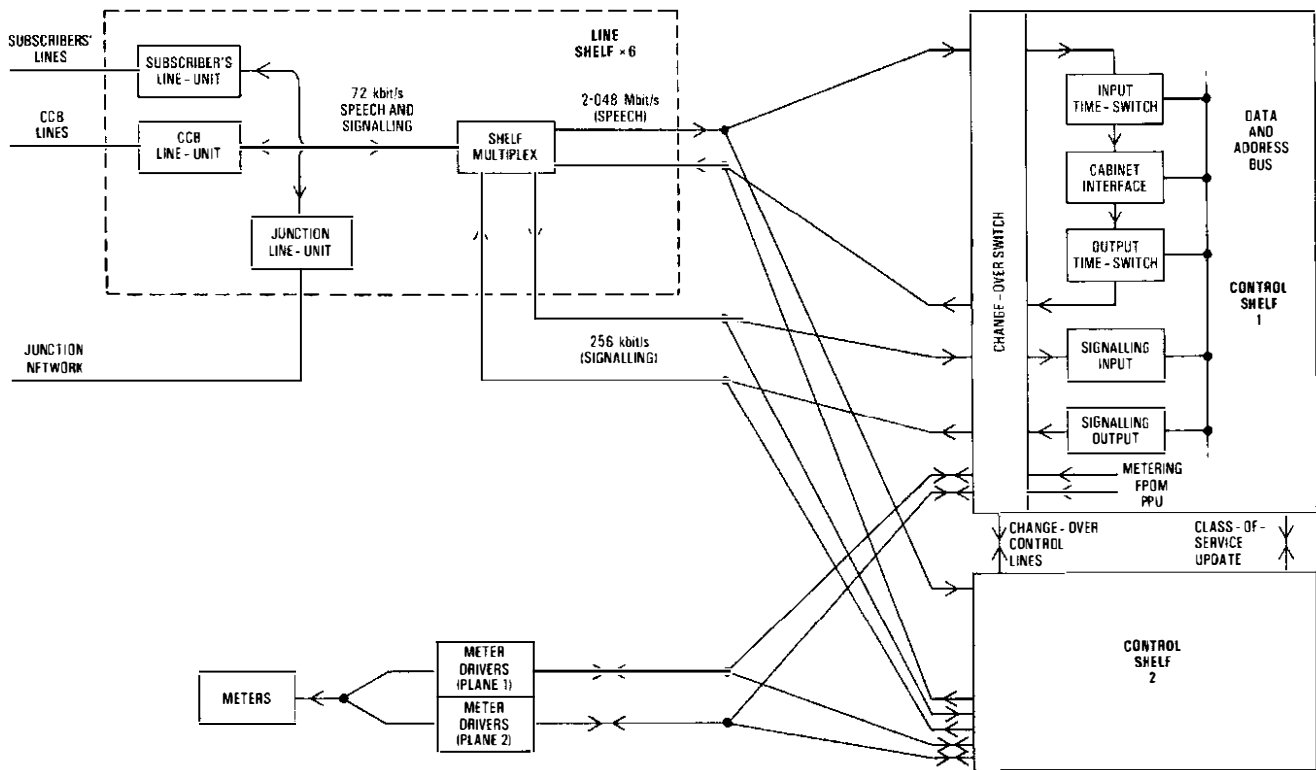


FIG. 1—Block diagram of the UXD5

access to the line shelves at any one time. If a fault is detected on the working control shelf, an output from the processor circuitry, known as the *watchdog*<sup>1</sup>, causes the change-over card to initiate a change-over to the idle control shelf, but with loss of calls in progress. A routine change-over between control shelves is also made approximately every 24 h, but at a time when no calls are in progress.

A data link is provided between the two control shelves so that changes (such as class-of-service state) made to the database in one shelf can be passed automatically to the other shelf.

Digitally encoded speech from the shelf multiplexers is applied to non-blocking time-switches designed for the Monarch 120 system. The time-switch inputs include signals from a digital tones card and a conference unit (currently used in the UXD5 for various standard functions such as tone test and pay tone), as well as signals from the 6 line shelves. Similarly, signalling from the shelf multiplexers is applied to a signalling input card on each control shelf, which is scanned by the processors for signalling information. A signalling output card interfaces between signalling from the processors and the line shelves.

The provision of public network signalling and metering has placed an additional scanning load on the central processor unit (CPU); to assist with this load, a pre-processor unit (PPU) has been introduced on each control shelf. Both processors use the same design of board, the differences being implemented by means of links. In each case, an 8085 microprocessor provides the processing power and is provided with an attendant watchdog circuit, random access memory (RAM), read-only memory (ROM) and serial data-handling devices (universal synchronous/asynchronous receiver/transmitter (USART)). Alphanumeric displays on the front of the board are used to provide limited diagnostic information.

Primarily, the PPU handles junction scanning and dialled digit reception, for which a scan every 8 ms is required; the CPU deals with a slower (128 ms) scan used for the detection of subscribers' loop conditions and for the handling of call-processing routines. The use of two processors was necessary

to handle the volume of processing work and to provide sufficient serial USART links for purposes such as metering, without requiring major redesign of the Monarch 120 processor board.

The two processors on each control shelf are arranged to use common data and address busses. The PPU has priority and can interrupt the CPU by use of a *hold* signal.

The main program is held on two ROM cards, each capable of storing 48 kbytes<sup>2</sup> of information; 16 kbytes of RAM is also provided. Both types of storage use the same cards as those used in the Monarch 120 system.

### Metering

The meter-driver cards are driven from the PPU over duplicated serial data links controlled by USARTs and are accessible by either control shelf.

Each meter-driver card controls the operation of up to 60 meters. The card carries a single-chip microcomputer (Intel 8748), which receives a request to operate a meter, checks the message, holds the meter operated for the appropriate length of time and checks that the meter is being correctly driven. Relay driver integrated circuits are used to interface between the low voltage microcomputer and the meters, which operate from the -50 V battery.

Up to 4 meter-driver cards can be connected to a bus, which carries messages to and from the PPU. When a meter is to be operated, an 8 bit serial message is sent to the bus by the PPU, the first 2 bits of which identify the driver card. The microcomputers on each of the 4 cards receive the message, but action is taken only on the card addressed by the first 2 bits. The remaining 6 bits of the message identify the meter that is to be operated. The microprocessor decodes the message and first checks the electrical conditions at the meter terminals to confirm that the meter is not already operated. If this test is successful, a signal is sent to the appropriate meter driver to operate the meter and the conditions are again checked, this time to ensure that the meter has been driven correctly. After a period of 150 ms, the meter is

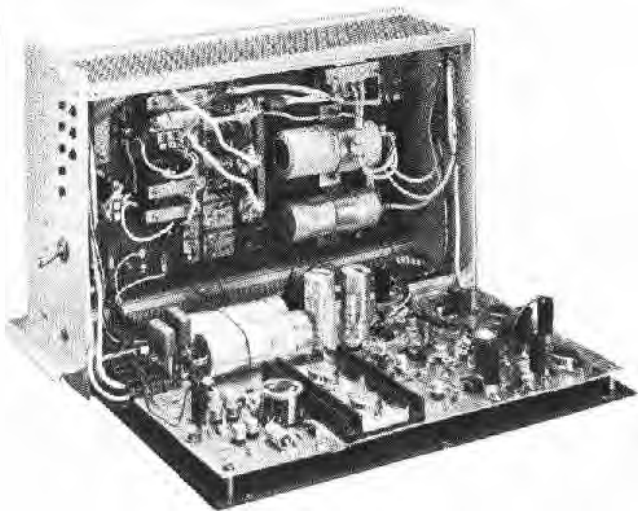


FIG. 2—DC-DC converter

released and a final check is performed to ensure that the meter is no longer operated. Finally, if all of the checks are successful, the microprocessor returns a copy of the original message to the exchange PPU via the bus to verify that a meter pulse has been applied.

The entire meter-driver structure is duplicated (as shown in Fig. 1). In the event of a fault on an operational meter-driver card (detected by a wrong or missing reply message), no further messages are sent to that card. Further requests to operate one of the 60 meters thereby affected are routed by the PPU via the second bus to the duplicate standby card, and an alarm is generated. In the unlikely event of a failure in the standby card, no further attempt is made to charge any of the 60 affected customers until maintenance action is taken. At intervals of 24 h, the functions of worker and standby meter-driver cards are interchanged to ensure that hidden faults have not developed in the standby unit.

### Power Supplies

The control and line shelves are powered from specially designed high-efficiency DC-DC converters (see Fig. 2), each providing up to 100 W of power from the exchange battery at voltages suitable to drive the digital circuitry. For example, each control shelf is provided with a dedicated DC-DC converter which provides 54 W at +5 V, 2 W at +12 V and 3 W at -12 V at an overall efficiency of 80%. The power requirements of the digital circuits used for metering are provided from the control-shelf converters.

One DC-DC converter is provided for each pair of line shelves; by this means, only partial loss of service occurs under fault conditions. The DC-DC converters use switching techniques and ferrite components for efficiency; the converters are also designed to achieve high availability.

The power consumption of a 100-line UXD5 is 250 W with no traffic, and 330 W when 14 calls are in progress.

### PHYSICAL REALIZATION OF THE UXD5

The 150-line exchange is contained in two cabinets, secured together to give an overall size of 1114 mm × 595 mm × 2130 mm. The cabinets are designated *A* and *B* respectively, and contain standard-size shelves which accommodate equipment cards of 318 mm × 203 mm. The equipment cards are interconnected by means of a backplane in which wiring is wrapped automatically during production. A front view of the cabinets (with covers removed) is given in Fig. 3.

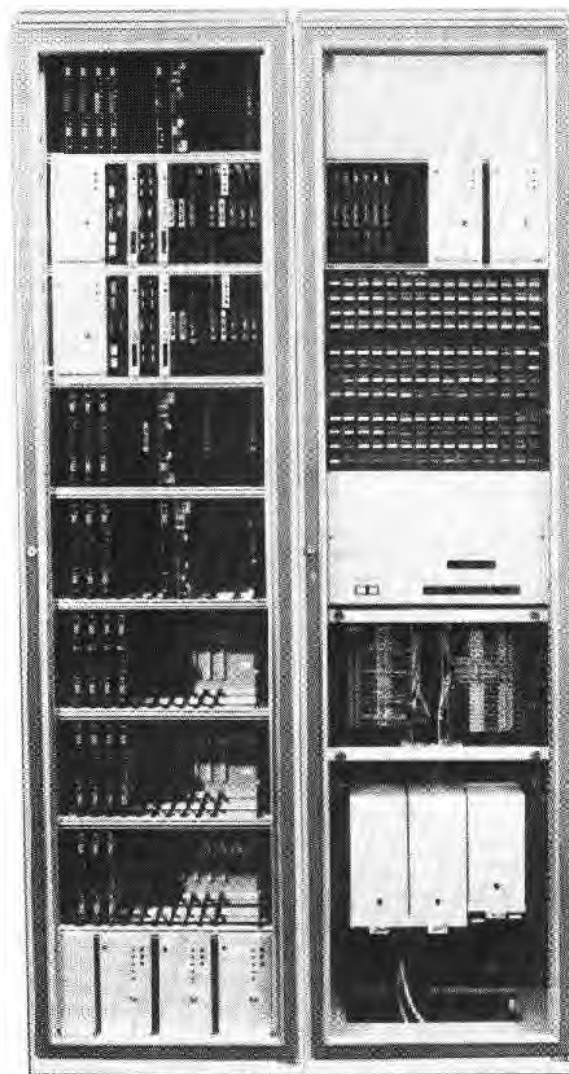


FIG. 3—Front view of the UXD5 equipment cabinets

### A-Cabinet Equipment

The A-cabinet (shown on the left-hand side of Fig. 3) houses two more shelves than a Monarch 120 cabinet. The second shelf position contains the duplicate control shelf, and an extra line shelf is installed at the top of the cabinet to provide facilities for an extra 24 customers' lines and 8 junction circuits. The extra line shelf uses a spare time-switch port provided in the Monarch 120. At the bottom of the cabinet are 3 line shelf DC-DC converters, mounted in slide-in-units, and a Ringer No. 13A, also mounted in a matching slide-in-unit.

### B-Cabinet Equipment

The B-cabinet (shown on the right-hand side of Fig. 3) houses equipment required to connect the UXD5 to the existing network; that is, the equipment that enables the UXD5 to operate as a direct functional replacement for a UAX12. The cabinet houses subscribers' meters and their associated duplicated driver cards, an alarm panel, the MDF, miscellaneous relay-sets and the 50 V power distribution fuses.

Three pairs of meter-driver cards are contained in a standard shelf; connexion is made to the meter panels below by multi-way ribbon cable terminated with plugs and sockets. The meters are arranged in 3 panels, each holding 60 meters in four rows of 15.

Below the meters is the alarm panel and associated indi-

indicator lamps, which report the status of the exchange. Also provided on the panel are buttons to reset the meter-driver cards after maintenance work; switches are provided which disable the alarm indicators while the lamps are tested.

The compact MDF is built from the recently introduced Jacks, Test No. 39 and No. 40. Each block carries 100 pairs; those on the line side of the exchange are protected by gas-discharge tubes. An intermediate distribution frame is not required since directory-number to equipment-number translation is performed by the exchange software and the exchange is not sensitive to the distribution of traffic load between the line units or shelves. Therefore, line pairs are jumpered from the line side of the MDF directly to the exchange side, where terminations are arranged in equipment number order. Direct test access to each line is available at the MDF as each pair can be split by a specially designed plug inserted in the terminal block.

Power from the exchange battery enters the UXD5 at the bottom of the B-cabinet and is distributed as required via fuses. Indications of fuse failure are connected through the processor in the A-cabinet and an alarm is raised when a fuse fails.

Finally, space is provided for up to 3 jack-in relay-sets. A WB700 receiver is provided to receive local call-timing pulses from the controlling GSC. To allow full flexibility of use, all connexions to the relay-set sockets appear on a miscellaneous connexion strip mounted in the rear of the cabinet.

## FACILITIES

The UXD5 provides normal Strowger facilities, with UAX12 variations such as combined level 1, 9 and 0 junction working, trombone junction testing and remote test number.

Loop disconnect, SSDC2 and SSAC8 facilities are available for junction signalling; the resistance limit for incoming loop-disconnect signalling is 2000  $\Omega$ . All level 1, 9 and 0 traffic is routed to the parent GSC, and side routings are available on level 8. The numbering range used on trial models has generally conformed with the UAX12 numbering scheme; however, UXD5 is capable of operating within a linked-numbering scheme.

The traffic capacity of the exchange is limited by the number of call records to 23 erlangs while providing a grade-of-service of 0.01. The occupancy of the control sets a limit of 1700 busy-hour call attempts. However, the time-switch is non-blocking, and has no effect on traffic capacity.

The transmission aspects of the system have been designed, as far as possible, to keep speech levels at the GSC similar to those from a UAX12. There are, however, two restraints

upon transmission through the exchange. Firstly, the incoming analogue signal must be adjusted to ensure that the signal presented to the CODFC does not cause overloading; secondly, since UXD5 is 4-wire switched, the 4-wire loop must be unconditionally stable.

The exchange uses a 25 mA constant-current feed on subscribers' lines and, as the telephone regulator is inoperative at this level of current, a gain adjustment is provided on the line card to cater for short lines of up to 4 dB line loss and long lines up to 10 dB loss. Service can be provided to long lines exceeding 10 dB loss by using a modified line-card. At present, the DC signalling limit for subscribers' lines is 1500  $\Omega$ , excluding the telephone instrument.

Subscribers' class-of-service status is stored in the exchange configuration database, which can be read and modified using a teletype. Access to the database is restricted by means of passwords. New lines can be provided simply by plugging-in extra line cards, providing MDF jumpering and activating the lines in the database. Maintenance and diagnostic facilities can be accessed using the same teletype, and will generally isolate faults down to card level. However, as these automatic tests are not absolutely certain of isolating all faults, confirmation by maintenance staff is required. Results from the tests are stored in a fault record, which can be read as required by maintenance staff. The diagnostic facilities also allow the maintenance staff to run particular tests on suspect equipment.

Initially, production UXD5 exchanges will be provided with adaptors for 16 shared-service lines, but the space occupied by the adaptors will possibly be needed for new equipment providing advanced facilities as shared service is phased out.

## FEASIBILITY STUDY TRIAL

The UAX12 site chosen for the feasibility study is at Glenkindie, in the Aberdeen area. The exchange serves a rural community and has 93 exclusive lines, 3 CCBs, and 8 bothway junctions to the GSC at Alford. The connexions include both very short lines and some lines which are beyond the present transmission limits, but which are within proposed new limits.

For the purposes of the feasibility study, the existing UAX12 is retained on site, although some rearrangement of the UAX12 racks was necessary to accommodate both exchanges in the existing building (see Fig. 4). The ability to locate both exchanges in the one room indicates just how small the UXD5 is in relation to its predecessor.

A multiple relay switch is provided so that either the UXD5 or the UAX12 can be connected to provide service. The UAX12 is returned to service automatically should the UXD5

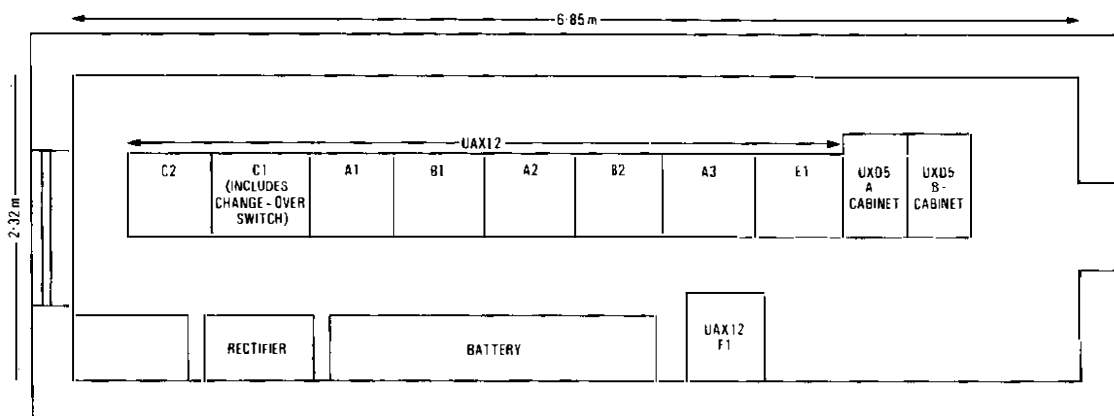


FIG. 4—Equipment layout for the feasibility study trial at the Glenkindie exchange

be rendered inoperable by failure of both control shelves or by failure of the power to one of the DC-DC converters supplying the line shelves.

For the feasibility study trial, it was necessary to increase the capacity of the exchange batteries to supply the joint power demand when the UXD5 carries no traffic and the UAX12 carries all traffic. If the mains supply fails for longer than 5 min, the UXD5 is switched off to conserve battery power. In this case, the UAX12 provides service. Urgent alarms in the UXD5, or a change-over to the UAX12, are signalled remotely by a change to the number unobtainable (NU) tone on the alarm-test number.

The trial was started on 31 July 1979. Some initial deficiencies were discovered during the early stages of the trial, but these have been easily corrected. In particular, the need to reduce the susceptibility of the line cards to lightning was highlighted, and improved protection was provided and will be provided on all future models.

#### FURTHER DEVELOPMENT OF UXD5

The BPO is now producing a further 12 exchanges for laboratory and network trials. These are based on the Glenkindie design, but some minor changes have been implemented as a result of experience with the trial model. Nine of these exchanges are being installed in the Dundee and Edinburgh telephone areas for evaluation trials.

A contract has been placed with Plessey Telecommunication Ltd (PTL) for industrialization of UXD5 design and the production of a number of prototype exchanges. It is expected that production exchanges will become available during 1981. A joint BPO/PTL study has been set up to identify possible enhancements for both the home and export markets. A substantial export market currently exists for a very small exchange of this type, and the initial phase of the study included an assessment of export requirements.

Further development of UXD5 is envisaged in the following areas:

(a) To reap maximum benefit from export opportunities and for additional flexibility within the home market, it is proposed to increase the maximum size of UXD5 to 600 lines.

(b) Consideration is being given to the development of additional services; namely, abbreviated dialling, automatic advice of call duration and charge, automatic alarm-call, call barring, call diversion, call-waiting indication, repeat last call

and 3-party calling. The Monarch 120 system offers a range of supplementary services which will form the basis for equivalent facilities on UXD5.

(c) Advanced signalling development is in hand to provide CCITT R2 signalling and direct connexion to 30-channel pulse-code modulation systems. In addition, the development of common-channel signalling is under consideration.

(d) The design is being enhanced to provide advanced service facilities, including remote print-outs and remote interrogation of maintenance and diagnostics. Advanced traffic-recording facilities are being considered for development at a later stage.

(e) An itemized billing system is under development, and remote read-out facilities for both bulk and itemized billing systems will be provided.

#### SUMMARY

The UXD5 is a small, high-technology telephone exchange designed for use in rural areas. It is of extremely economic design due to its commonality with the Monarch 120 PABX; approximately 75% of the cards in a fully equipped UXD5 are the same as those used in the Monarch 120 system. The design is highly flexible as the exchange is software controlled, and a high availability is offered due to duplication of the control and switching equipment.

The unit design of UXD5 leads to ease of installation, and sophisticated diagnostic facilities are provided to assist maintenance.

A feasibility trial of UXD5 has indicated that the system has considerable potential and an additional 9 models are now being installed in the BPO network for further evaluation of the design.

The design of UXD5 is now being enhanced for export purposes and to provide advanced facilities for the home market. Production exchanges are scheduled to be available during 1981.

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