Partial Call Queueing on Auto-Manual Sleeve Control Switchboards

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Introduction

The British Post Office has for some years been giving considerable thought to the problem of the *unfortunate call*, that is, a call to an exchange operator which has waited a long time before being answered, in relation to the average.

The introduction of multiple appearances of answering jacks and lamps has made the problem more acute, since a greater number of answering lamps are located in front of each operator

When a subscriber or manual operator dials the appropriate code for gaining the attention of an operator, the call is routed from selector levels via an auto-manual relay set to the switchboard. The relay set operates a lamp relay which causes the call to be displayed at regular intervals round the switchboard in front of several operators. Each operator not already dealing with a call may answer by plugging a cord into the jack associated with the calling signal and normally there is little chance of a call being left unanswered for more than a few seconds.

When the traffic is heavy, several calls may be displayed in front of each operator who has no record, except perhaps her memory, to indicate which of the calls was displayed first thus the operator may answer any of the calls displayed, and a random method of answering results. Under these conditions a call may thus be left unanswered for longer than average and becomes an *unfortunate call.*

Certain classes of calls, indicated on the switchboard by different lamp caps, require more complicated operating procedure and demand more supervision on the part of the operator and it is to be expected that the operators tend to leave such calls in favour of the more normal calls. Clearly then such calls might easily be kept waiting for some time and become *unfortunate.*

At many exchanges the main criterion of the service given to the subscriber is the average *speed of answer* time but it is now considered that it is much more important to reduce the waiting time of the *unfortunate calls* that have waited a long time and that the average waiting time is only of secondary importance.

This would appear to give the best service from the subscribers' point of view, as they would be more likely to notice and complain about having to wait an appreciable time for a small number of calls than compliment the administration on a short average time to answer

New types of switchboards have been designed that store all the calls and display them to the operators in strict order of arrival. Such a scheme involving full queueing is incorporated in the new British Post Office cordless board but the scheme cannot readily be applied to existing switchboards.

Partial Call Queueing

The scheme to be described was designed to fit existing sleeve control system switchboards in such a way that no modification of any part of the existing equipment is involved. Whilst it does not claim to eliminate the *unfortunate call* altogether, the system minimises the possibility by a partial queueing system and sets a limit to the time that a call can remain unanswered.

In order to carry out a trial of the scheme, a rack of equipment was built in the Circuit Laboratory of the Engineer-in-Chief, British Post Office, and installed at Canterbury Exchange. As a result of experience gained with this equipment it was decided to build two more units so that the trial could be extended to gain further experience under different operating conditions.

The G.E.C. was asked to undertake the building of these two additional units which operate on the same basic principle as the Canterbury unit but with modified facilities and construction.

Principle of Operation

The principle of the scheme is that only a portion or batch of the potential calling signals appear on the switchboard. Calls arriving later are stored in the apparatus until the call that has been waiting longest in the batch displayed on the switchboard has been answered, whereupon the batch is refilled to the original size by withdrawing calls from the store and displaying them. The calls displayed will be answered in a random manner as previously but, because no further calls are displayed until the oldest waiting call in the batch has been answered, the duration of the *unfortunate call* is limited. Because of the random answering of calls within the batch, the scheme is termed *Partial Call Queueing*

The principle is comparable to a single file queue of customers entering a shop through a door which is normally open. When a certain number of customers have entered (a batch) the door is closed and until the customer who entered first has been approached by a shop assistant, no further customers are admitted.

The apparatus is capable of dealing with calling signals from 400 relay sets and up to 25 calls may be stored in sequence of arrival at the exchange. This quantity normally meets the instantaneous requirements of the 400 relay sets but should the calling rate exceed normal, or should the operators be prevented from answering calls for a short period, later calls are not taken into storage but are retained in a common pool, then accepted into the queue at random when calls are answered from the queue. Owing to the method of selection of calls from this pool it is impossible for a call to become truly *unfortunate*

Ringing tone is returned to subscribers from the time of seizing a relay set until the operator answers.

Display Control

Assuming the batch size is adjusted to 5 calls to be displayed and there are 10 calls stored waiting to be answered, the first call which arrived (that is, the 'oldest' call) will be the earliest call displayed and until answered is called the Head of Queue (HOQ) call. In the table below, the numbers 1 to 10 indicate the calls in order of arrival, 0 indicates the call is displayed for answer and S indicates the call is stored in queue order but not displayed. When a call has been answered it is indicated by X.

1	2.	3.	4.	5.	.	6	7	8.	9.	10.
0	0	0	0	0		S	S	S	S	S

First let us assume the calls are answered in order of arrival.

1	2.	3.	4.	5.		6.	7	8.	9.	10.
X	0	0	0	0		S	S	S	S	S

As the oldest or *HOQ* call has been answered and the batch size is limited to 5 calls, call No. 2 will now become the new *HOQ* call and call No. 6 will be admitted to fill up the batch displayed. If call No. 2 is now answered call No. 7 is displayed thus :—

1	2.	3.	4.	5.	6.	7		8.	9.	10.
X	X	0	0	0	0	0		S	S	S

and so on.

Next let us assume the calls displayed are answered in reverse order of arrival, that is, 5, 4, 3, 2, 1 Owing to the batch not being refilled until the oldest call is answered, call No. 6 will not be displayed until call No. 1 is answered, thus :—

1	2.	3.	4.	5.	6.	7	8.	9.	10.
0	X	X	X	X	S	S	S	S	S

Then when call No. 1 is answered the next batch of 5 calls (6, 7, 8, 9 and 10) will be displayed.

1	2.	3.	4.	5.	6.	7	8.	9.	10.
X	X	X	X	X	0	0	0	0	0

More usually the calls will be answered in random order from the displayed calls.

Thus say calls No. 2, and 4 are answered, no further calls will be displayed.

1	2.	3.	4.	5.	6.	7	8.	9.	10
0	X	0	X	0	S	S	S	S	S

then call No. 1 is answered, No. 3 will then become *HOQ* and No. 6 and 7 will be displayed.

1	2.	3.	4.	5.	6.	7	8.	9.	10
X	X	0	X	0	0	0	S	S	S

If now, calls Nos. 3, 6 and 7 are answered, No. 5 is *HOQ* and Nos. 8 and 9 will be displayed.

1	2.	3.	4.	5.	6.	7	8.	9.	10.
X	X	X	X	0	X	X	0	0	S

Calls Nos. 8 and 9 are then answered.

1	2.	3.	4.	5.	6.	7	8.	9.	10.
X	X	X	X	0	X	X	X	X	S

Thus 8 calls have been answered before call No. 5 which is unfortunate because it has not been answered in turn. The call would not be truly unfortunate unless it had waited a long time in relation to the average.

This illustration of random answering within the batch shows the reason for calling the queue partial. As no further calls are displayed until the *head of queue* is answered, the time which this call has to wait is limited and is the main improvement which the scheme gives when compared to a normal manual board without queueing facilities.

Apparatus

The equipment for an exchange with up to 400 multiple-answering equipments consists of two units only (1) a standard 4′ 6″ x 10′ 6½″ rack (Figs. 1 and 2), and (2) a supervisor's control cabinet (Figs. 3 and 4). At the top of the rack are the terminal strips as shown on Fig. 2, for cabling to the Intermediate Distribution Frame and the control cabinet.

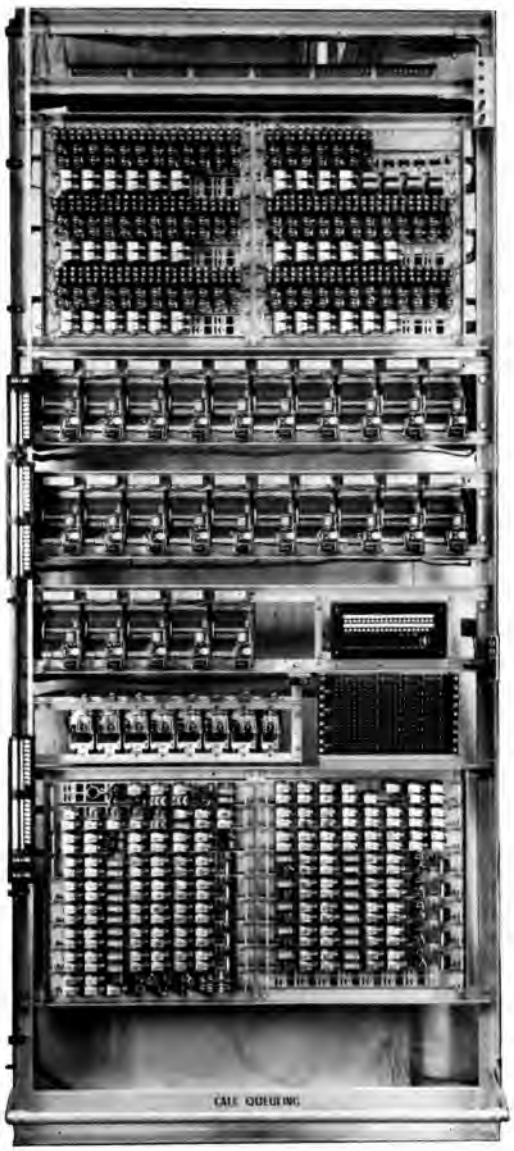

Fig. 1.—Front view of apparatus rack.

Below the terminal strips are the rectifiers, resistors and change-over relays associated with the 400 circuits which are multiplied to the banks of the 25 motor uniselector linefinders. These linefinders form the queue with a storage capacity of 25 and occupy two and a half shelves, the remaining half shelf being filled by a routine test panel used for maintenance purposes. On a shelf below are eight uniselectors used as follows :—

Two for the control of the number of calls displayed.

One for an allotter which takes into use each of the linefinders in turn.

Four for measuring the waiting time of calls on four selected linefinders.

One for measuring the waiting time of the call occupying the head of the queue.

At the end of the shelf are strips of sockets by which, using links, plugs and cords, it is possible to connect up the meters as required to the waiting time measuring circuits.

Fig. 3.—Supervisor's control cabinet.

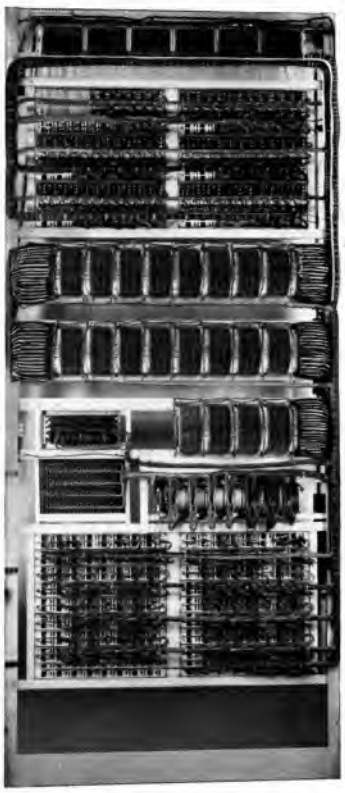

Fig. 2.—Rear view of apparatus rack.

The bottom of the rack is occupied by plates of relays for controlling the allotter, 25 linefinders, waiting time measuring circuits and various other miscellaneous circuits. The wiring side of the rack is shown in Fig. 2.

The supervisor's control cabinet is about 22″ wide, 18″ high and 12″ deep, and has a hinged front steel panel on which are mounted various control apparatus and indicators. The rear panel is removable for easy access to the wiring (Figs. 3 and 4).

On the left of the panel is a rotary switch for controlling the maximum time that a call can occupy the head of queue before the alarm lamp on top of the cabinet lights and a buzzer inside the cabinet is sounded. On the right is another rotary switch which determines the maximum number of calls to be displayed simultaneously which can be varied from 3 to 11

Fig. 4.
Rear view of the Supervisor's control cabinet.

In the centre is a ring of 25 lamps, one for each linefinder, which indicates the line finders in use, and inside this ring is a meter which summates the total number of calls waiting. In the centre of the panel are 40 meters, which can be connected by the links and sockets on the rack, to provide statistical information.

At the bottom left is a buzzer cut off key and on the right a key which controls the change over relays to restore from queueing to the random answering condition. Between these are 25 push keys, and lamps which indicate the linefinder carrying the *head of queue* call. In the case of a fault any linefinder can be locked out of service by pressing the appropriate key

Method of Operation

When a call is routed to the manual board for the attention of an operator, a contact in the incoming manual board relay set operates the lamp relay as described earlier This connexion is shown in the schematic diagram (Fig. 5) as the line between terminals A and B on the distribution frame.

In order to add the partial call queueing equipment to an existing sleeve control manual board, the only modification required is to disconnect the jumper on the distribution frame between terminals A and B and to rejumper so as to include the queueing equipment shown in the lower part of the diagram.

If the queue on/off key is operated the connexions are in effect as before and the queueing equipment is isolated. This facility enables the equipment to be routine tested, or taken out of service should a fault occur, without interference to normal traffic.

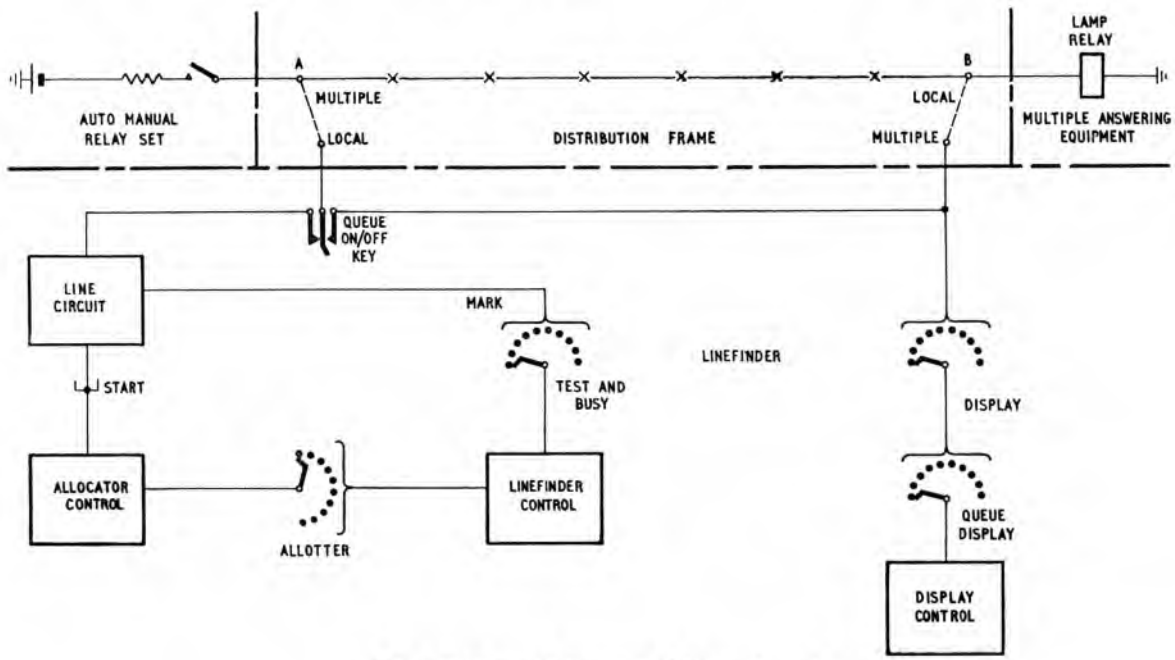

Fig. 5.—Schematic diagram of the equipment.

Thus it will be realised that this equipment is simple to instal and is readily put into or out of service as the supervisor considers necessary

Whilst the schematic diagram shows the queue on/off key directly controlling the circuit, this representation is only diagramatic as one key contact per circuit would be required. As the equipment may control calling signals from 400 multiple answering equipments, 68 changeover relays perform this function, these relays being controlled from a single contact on the queue on/off key which is mounted on the supervisor's control cabinet.

With this key in its normal position, each lamp lead from the incoming manual board relay sets is connected to one of the 400 line circuits. This line circuit comprises a resistor and rectifier, connected as in Fig. 6.

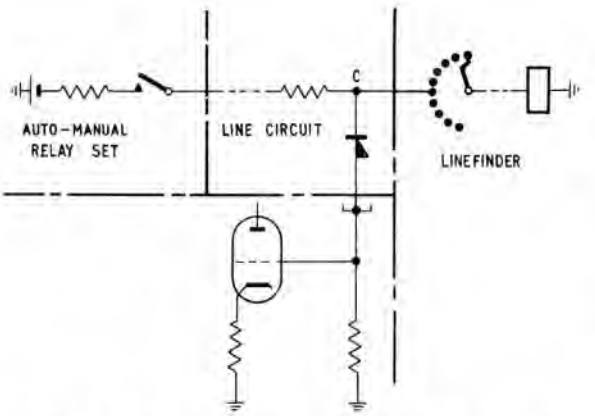

Fig. 6.—Schematic diagram of linefinder switching.

When the contact operates current flows through the rectifier and causes the bias of a valve to be increased so that the anode current is cut off and consequently a relay in the anode circuit releases. The release of this relay causes the linefinder, which has been preselected by the allotter, to rotate over its bank contacts, testing for the battery calling condition connected via the auto-manual relay set contact and line circuit resistor When the marked contact has been found the linefinder rotation is arrested by control relays in the allotter circuit and a low resistance relay is connected to the linefinder testing wiper to prevent other searching linefinders from stopping on the multipled appearance of this contact. The low resistance relay has two further functions firstly, to lower the potential of the connexion C in the line circuit so as to allow the bias of the valve to revert to its normal condition (that is, the start condition is cancelled) and, secondly, to hold the linefinder until either the operator answers or the calling subscriber abandons the call.

An important feature of the system is that all 25 linefinders have access to all of the 400 relay sets. The motor uniselectors used as linefinders have 16 wipers, each wiper rotating over a bank of 50 contacts. It will be seen from Fig. 5 that the circuit conditions require only two wipers and banks, one for marking and testing and the other for display control. Thus with the uniselector described we have eight such pairs of wipers, each pair hunting over 50 contacts, making 400 in all. The 400 display control wires are multipled over the 25 linefinders in a similar manner to the marking wires and are connected to the corresponding 400 lamp relays. When a linefinder has found a line circuit corresponding to a certain auto-manual relay set it will also connect the corresponding lamp relay to the display control circuit.

These wipers are also connected via linefinder control relays to the queue display switch banks. This is in fact two 8-bank 25-contact uniselectors arranged to step in synchronism.

The number of linefinders engaged at any one instant corresponds to the number of calling subscribers and as they have been pre-selected by the allotter the linefinders are engaged in the same time sequence as the subscribers initiate calls. Thus, as the order of selection of linefinders is predetermined by the wiring of the allotter switch, then the queue switch may control the linefinder banks connected to the lamp relays in an order corresponding to the position in the queue. The queue switch is arranged so that it is always located on the oldest call in the queue (i.e. the *head of queue*). Further banks of the queue switches arrange the display of calls by operating the lamp relays via the linefinder banks.

A wire from each linefinder is terminated on the queue switch bank and the operation may best be explained by reference to Fig. 7

Normally a wiper on a uniselector bank occupies only one bank contact at one instant. However, if it is imagined instead to be bridging several bank contacts, then several lamp relays (the selection of lamp relays depending on the position of the linefinders) may be operated simultaneously. When the *head of queue* (contact 1 with queue switch as shown) is answered contact 5 will be connected thus refilling the display

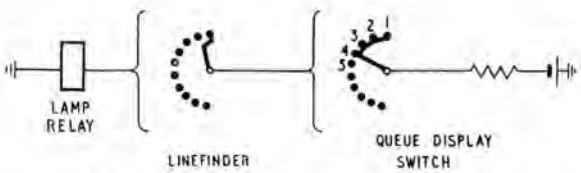

Fig. 7.—Schematic diagram of display control.

In this case the maximum number of calls which can be displayed is shown as four and the answering of calls from the queue will follow the principle described above. By varying the number of contacts bridged the maximum number of calls displayed can be varied.

As no uniselector with this design of wipers is available, several banks on a normal selector are connected in a staggered multiple which produces the same result. A rotary switch on the supervisor's cabinet connects this multiple to the wipers of the switch and so controls the maximum number of calls which can be displayed.

When a call is answered by the operator the contact in the auto-manual relay set operating the apparatus is released and consequently the corresponding linefinder is released to be reallotted to subsequent calls.

The time each call occupies the head of queue position is measured by the *head of queue* waiting time measuring circuit. A rotary type switch mounted on the supervisor's control cabinet is used in conjunction with this circuit to vary the time a call can remain unanswered at the head before an alarm is operated. The alarm time-delay is variable between 12 and 120 seconds. The alarm is indicated audibly by a buzzer in the supervisor's cabinet and visibly by a lamp on the top of the supervisor's control cabinet and by lamps multipled to spare section supervisor's lamp positions along the switchboard suite.

The normal reason for the alarm operating will be due to the switchboard traffic increasing and consequently too few operators being present to deal sufficiently promptly with the traffic. However, the alarm may be given due to a fault condition such that whilst the apparatus has queued the call it fails to display the call on the switchboard and consequently the operator is unaware the call exists.

The first alarm condition may be overcome by increasing the operating staff but the second is a fault condition and means are provided to locate the fault. As the *head of queue* call is indicated on one of the 25 lamps on the supervisor's cabinet she merely has to operate the adjacent key which then locks out the linefinder from the queue so that further calls may be displayed. This holds the linefinder so that the faulty lamp circuit can be identified from the wiper position on the banks.

The alarm lamps and buzzer are switched to a circuit which gives an interrupted alarm signal at a frequency of 0.75 seconds on, 0.75 seconds off, in the event of a failure of the equipment. The supervisor then operates the queue on/off key, so transferring calls to the normal unqueued random answering method.

The ring of 25 lamps on the supervisor's control cabinet is provided to give a " picture " of the conditions existing in the queue. Each lamp is lit when a queue place is occupied (that is, each lamp indicates a waiting call and glows irrespective of whether the call is displayed on the switchboard or not). When a call is answered the lamp is extinguished. As the 25 linefinders (positions in the queue) are allotted in consecutive order, the effect on this display is an arc of glowing lamps moving round the ring. The arc varies in length depending on the number of calls in the queue and

as calls are answered in random order from the trailing end of the arc of lamps (that is, from the batch on display) the effect is of the arc being broken as it rotates round the ring of lamps.

The rate of rotation of the glowing arc indicates the rate at which the traffic is handled by the switchboard.

As the display gives a very good indication of conditions in the queue a duplicate display is provided on the routine test panel on the apparatus rack.

The meter which summates the total number of calls waiting is positioned in the centre of the ring of lamps and in some respects duplicates the function of these lamps as the number can also be obtained visually by counting. When the traffic is small and the rate of answering correspondingly small, it is easy to count the number of lamps glowing, but this becomes increasingly difficult as the traffic increases owing to the higher rate of rotation of the arc of lamps and the broken effect of the arc due to random answering within the batch of calls displayed.

The meter is consequently used to fulfil the function rapidly and accurately A ratiometer type of instrument is used to prevent battery voltage variations affecting the accuracy of the reading.

The forty meters of the call register type are connected by plugs and sockets on a panel at the end of the uniselector shelf, for the following purposes :—

Several meters are used for recording the number of calls which wait a predetermined time before being answered (waiting time). For example, these predetermined times may be 1, 2, 3, 4, 5, 6 10, 11 20, 21 30 seconds or any other time for which it is desired to obtain the number of calls having this waiting time.

The provision of this equipment on sleeve control switchboards not only gives the subscriber a much improved service but allows the switchboards to be more efficiently staffed.

To provide a continuous sampling of the service for purposes of quantitative analysis any four of the queue positions may be selected for measuring the waiting time of all calls which are queued in those positions.

One meter per sampled queue position records the number of calls timed.

By statistical analysis of the above information the waiting time distribution of all calls passing through the equipment may be obtained.

Two further meters record the total calls handled by the apparatus as a whole and the number of times the queue is full.

This information has proved of great value and for the first time reliable and accurate information on the service given by the operators can be obtained.

Equipment such as emergency calls, service extensions, interception, meter observation and fixed time monitor and transfer circuits, are not multipled over the switchboard and are not included with the queued equipment.

Conclusion

The first rack and supervisor's control cabinet was supplied for installation in a trunk control centre in London where there are at present 100 position. The amount of traffic handled by these positions is only sufficient to utilise one call queing equipment as long distance calls require more than average setting up time and supervision.

The second equipment was supplied for Middlesbrough. This is an interesting application as there are two suites of positions and the service may be compared on one suite under queueing with the other under random answering conditions. There are about 30 positions on each suite at this exchange.