No. 125.

THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

# The Development of Automatic Routiners in the British Post Office.

BY

A. SPEIGHT, A.M.I.E.E.

**A PAPER**

*Read before the London Centre of the Institution on the 12th November, 1929.*

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# INTRODUCTION.

(1) With Automatic Telephony as the accepted programme of the British Post Office, it is only natural that the question of performing routine tests in an automatic manner should have received consideration.

(2) Other administrations are similarly occupied, but on account of the variety of automatic systems in use, it is necessary, in this paper, to confine attention mainly to automatic routiners as applied to the " Strowger " or " Step-by-Step " system and particularly to the " Director " system employed by the British Post Office.

(3) It should be stated at the outset that auto routiners are still in their infancy and therefore no claim is made that the matter is dealt with fully.

(4) So far as the author is aware, little or no literature on automatic routiners is available. Articles by Messrs. W. E. Chinn and J. S. Young, of the British Post Office, have appeared recently in the Journal of the Institution of Post Office Electrical Engineers, but these articles describe, mainly, circuit operations.

In this paper no attempt is made to deal with circuit detail, but rather to place on record the main points which have arisen during the development of automatic routiners, for maintenance purpose, by the British Post Office. Many of the matters dealt with are, however, equally applicable to systems in use by other administrations.

(5) It is necessary to refer, briefly, to the earlier periods before automatic routining was accepted by the Department. For many years manual routine testers had been used and, as such testers are well known, there is no need to enlarge on them. It will suffice to state that the testers were portable and had to be connected by plug and cord to a jack on the switch to be tested. The various tests were applied, one at a time, by means of keys operated by the testing officer. In other words, the testers were purely " manual " in operation in contradistinction to " semi-automatic " or " full automatic " testers.

(6) Sir William Noble, a former Engineer-in-Chief to the British Post Office, visited the United States of America in 1919 and learned that automatic routining was included in the specification for the " Panel " system. It was under-

stood, however, that the arrangements were of a very complex character.

In 1922, Messrs. M. Ramsay and J. Hedley, also of the British Post Office, visited the United States and their investigations confirmed the previous conclusions as regards complexity.

(7) Meanwhile, Mr. W. Wheeler, of the British Post Office, had designed and developed a portable tester, semi-automatic in operation, for use in connection with final selectors. Access to the switch to be tested was gained in the same manner as with the manual tester; but a distinct advantage resulted from the introduction of apparatus which caused the required tests to be applied automatically once a key was operated.

(8) The installation of the " Director " system in the London Area necessitated a review of the whole question. It was therefore decided to go a step further and assemble the testing apparatus on a rack; also to instal access switches and permanent cabling to provide means whereby the tester could be connected with any one of a group of items to be tested. Such a tester has been termed an " Auto Routiner," the word " Routiner " obviously being a coined one. This term may not be the happiest choice, but, like many others used in connection with automatic telephony, has become accepted as having a definite meaning.

## REMARKS ON JUSTIFICATION AND APPLICATION OF AUTO ROUTINING.

(9) Considerations which have a bearing on whether auto routining is justified are:—

(*a*) *Switch complication both as regards electrical circuit and mechanical operation.*

Such complication necessitates the covering of many functions and therefore the routining apparatus has to be complex. This complexity aspect applies equally to manual and auto routiners and questions of bulkiness, lack of portability and obstruction of gangways between apparatus racks therefore arise. Further, more expert staff is required and the delegation of routine testing to unskilled staff becomes impracticable.

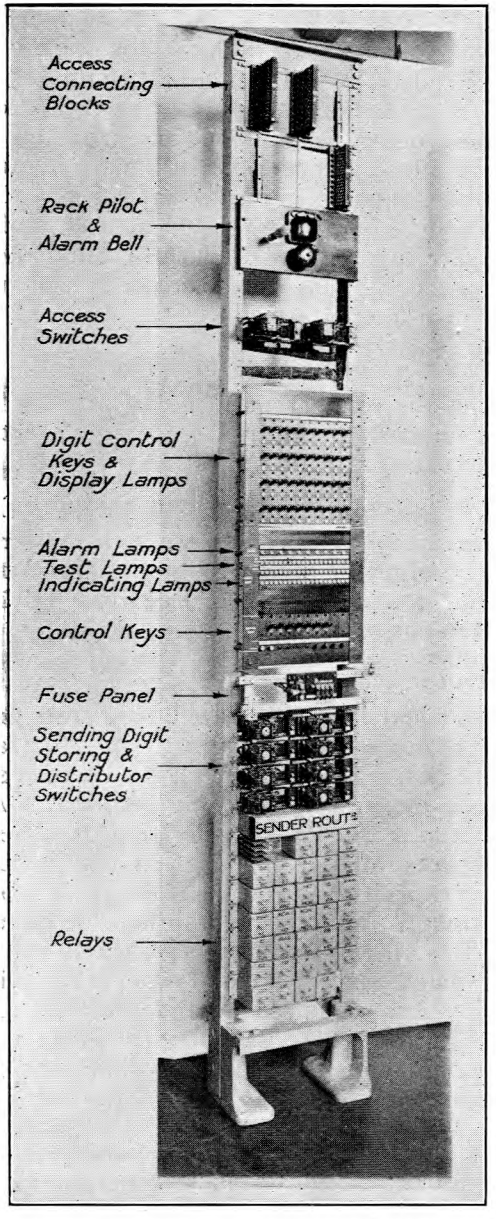


FIG. 1.—TYPICAL EXAMPLE OF A ROUTINER (for 4-digit Senders).

(*b*) *Frequency of tests.*

A certain proportion of automatic apparatus, such as directors, coders, senders, etc., is " common " plant and is used for a few seconds only when calls are being set up. These items are thus subjected to an extremely heavy traffic load and consequently more frequent routine testing is essential. In fact, as regards this type of apparatus, which must be tested at least daily in order that the service may be safeguarded, automatic routining would appear to be the only method by which the necessary tests can be performed.

(*c*) *The number of items to be tested.*

When the number of items is large, it becomes a physical impossibility to make a manual test if a daily test is necessary.

(*d*) *Avoidance of interference with normal traffic.*

To avoid this it may be necessary to carry out tests during the night or at other times of slack traffic, thus introducing questions of inefficient night work, difficulty of adequate supervision, etc.

(*e*) *General inference.*

With manual routining the labour costs predominate and it is necessary to review the position at frequent intervals to ascertain whether results commensurate with the labour expended are being realised. With automatic routining such a consideration does not arise as, once the apparatus is installed, it can be used to its maximum capacity and routine testing can be carried out at more frequent intervals with little or no extra cost. In view of this, it is reasonable to assume that a higher grade of maintenance will result when automatic routiners are employed than is possible under manual routine conditions. Further, the psychological effect of relieving men of monotonous manual duties should be considered.

*Advantage of automatic routining.*

(10) The advantage may be summarised as follows:— A large amount of complicated automatic plant can be kept under more or less constant test, with minimum cost, thus furnishing the controlling staff with a true indication as to whether the plant is performing its function efficiently. The

human element is almost eliminated and therefore stringent testing can be carried on during the night, or other non-normal hours of duty, with the same precision as during the day.

*Possible disadvantage of automatic routining.*

(11) The main argument, often put forward, is that the item under test is not watched by a maintenance officer whilst the test is in progress. This question is always being raised and should, therefore, be dealt with somewhat fully. It may be asked whether it is necessary to watch, or listen to, an item under test. When the item comprises relays there does not appear to be any advantage in attempting to watch the relays operate.

When mechanical operations are concerned, it may be argued that it is advantageous to watch, or listen to, the operations, provided they do not take place so quickly that their action and sequence cannot be followed either with the eye or the ear. Whilst admitting that, *given a very skilled officer,* such a procedure may, under some circumstances, be of advantage, it is necessary to face the problems which large automatic exchanges have introduced and re-adjust our views on routine testing. Some aspects of this matter are given below :—

(*a*) Modern automatic apparatus is much improved in type and, whereas some benefit might have been gained by watching the earlier apparatus during operation, the later and more robust apparatus should not require it.

(*b*) Routine tests are performed to ascertain whether the plant is functioning correctly. The test condition should be a little more onerous than the worst practical condition and, therefore, a fault should be discovered before actual breakdown occurs, even when mechanical operations are concerned.

(*c*) It has been demonstrated recently, in certain automatic exchanges working under manual routine conditions, where switch operations are observed, that more frequent testing results in more faults. No definite reason can be given, but perhaps it is accounted for by the " tuning up " which a man observing the switch is inclined to perform. It may also arise because of the accidental knocking of switches, especially if gangway

space is restricted. Such a result supports automatic routining and leads one to the conclusion that it is desirable to leave a switch alone until it is really necessary that some adjustment should be carried out. This does not mean that the switch has ceased to give a good service, because the severity of the test (see (*b*) ) should take care of this.

(*d*) Whatever arguments are advanced for observing switch operations it has to be admitted that such a procedure, as a matter of course, is impossible in modern automatic exchanges, for the reasons already given in paragraph 9 (*a*). Further support is furnished in paragraph 13 which describes two schemes of auto routining adopted by some foreign administrations. These schemes are such that observing the apparatus is out of the question.

(12) The British Post Office compromised to the extent of providing facilities for observing a switch under test when locating a difficult fault. This facility, which is described in detail under " Remote control of reset feature " (para. 52), falls in the category of fault removal rather than routine testing.

*Application of auto routine tests.*

(13) The method by which the tests may be applied requires consideration.

(*a*) One method which has been proposed by a foreign administration is to " tee " on to two subscribers' lines during a disengaged period, set up a call between them, and check, broadly, the correct operation of all the plant concerned in the chain, the procedure being continued by seizing a further two subscribers' lines, and so on. This method has several disadvantages, notably (i) the inability to indicate the location of a fault which may be anywhere in the chain of switches, and (ii) possible interference with a subscriber's service. Many important features of intermediate apparatus are left untested, and the scheme may be classified as " Observation " or " Service sampling " rather than maintenance routine testing.

(*b*) A further scheme, placed in operation by another foreign administration, consists of routine-testing switches individually but only for one function

at a time, *i.e.*, different test cycles are employed for different functions. This would appear to be unsound, because it is not possible at any time to say that a switch is " O.K." as regards all its functions.

(*c*) The method adopted by the British Post Office is to routine-test switches individually; and a test of all the functions of a particular switch is completed before passing on to the next.

(14) It should be remarked that method (*a*) has the advantage that a certain number of outlets, or link connections between switches, are tested. In schemes (*b*) and (*c*) very little, if any, of the link incoming to and outgoing from a switch is tested. The advantages of scheme (*c*) are thought, however, to be sufficiently real to outweigh the question of outlets or cabling links, which have a comparatively low fault liability and can, if necessary, be subjected to an independent test at infrequent intervals.

## DESIGN OF AUTO ROUTINERS.

*General outline of requirements.*

(15) A brief outline of requirements may be stated as follows:—

The auto routiner to be mounted on a rack and controlled by keys. When once started, the application of the requisite conditions for successive tests of the functioning of the switch to be applied automatically by " step-by-step " devices. Each function of the switch under test to be tested separately, as far as practicable. Each step forward movement to be dependent on the satisfactory performance of the function tested on the previous step, so that failure of any particular function will result in the arrest of the stepping mechanism.

Lamps to be provided to indicate which switch is under test and also the progress of the various tests. When a function fails under test, the relevant lamp to remain glowing and an audible alarm to be given.

The tests to continue, switch by switch, until some abnormal condition is encountered or the end of the test cycle is reached.

(16) Some of the points affecting the design of auto routiners are dealt with below.

*Routine testing to be considered when main circuit is designed.*

(17) It is of vital importance that possible methods of routine testing should be considered when the main circuit is designed. This may present difficulties, particularly when circuits are required at short notice, because the circuit designer merely sets out to meet a certain need and does it in what appears to him to be the simplest manner. The circuit may then be approved to allow the apparatus to be manufactured and at some later date when the question of routine testing is raised, radical modifications may be necessary. This is obviously an uneconomical procedure.

(18) When the main circuit has reached concrete form as regards essentials, the maintenance aspect should be considered and a definite scheme of routine testing, if required, formulated in order that any necessary switch test jacks for local access or cabled access points for auto routining, may be provided; as the designer of the main circuit is familiar with all its functions it would appear that he should also decide how the functions are to be adequately routined.

(19) Such a scheme would avoid the unsatisfactory position of a main circuit becoming a " fait accompli " and the discovery later that certain functions cannot be properly routine tested because of the way in which the various components of the main circuit are linked together. In other words, the maintenance aspect must be given prior consideration, as it is useless to design complicated circuits unless it is quite certain that they can be maintained at high efficiency with a labour expenditure which can be tolerated. The maintenance charges have to be borne throughout the life of the plant and it is far preferable to expend a relatively small amount of additional money in the early stages, thus saving heavy maintenance expenditure later.

*Access Equipment.*

(20) This term covers all the equipment which is required to enable the routiner to be connected with each item of plant, in a group, in sequence. It is usual to provide this access by means of rotary switches which are stepped as required. Switches having 25 outlets are employed and the number of ranks of switches depends on the number of items to which it is desired to obtain access. Three ranks are generally employed, these being designated:—

(*a*) Primary distributor (connects with secondary distributors).

(*b*) Secondary distributors (connect with access switches).

(*c*) Access switches (connect with actual item of plant under test).

(21) It is customary to mount items (*a*) and (*b*) on the routiner rack and the access switches on the main racks as close as possible to the items to be tested.

(22) When the number of testing leads requires more switch levels than can be accommodated on one switch, say greater than 8, an additional switch should be arranged in such manner that the second switch always steps to the same position as the first one. The testing leads should be distributed over the two switches in order to prevent the test commencing until this condition obtains.

(23) Assuming 20 outlets only to be used on the access switches and secondary distributors, it will be seen that 20 × 20 or 400 items are catered for. On the primary distributor as many outlets (1 per 400 items) as are required are used and multipled round the bank. The use of 20 outlets is convenient because it generally coincides with the rack and shelf arrangements of the plant items to be routined. Further, a standard type of lamp jack can be employed for the indicating lamps.

(24) It frequently occurs that complete shelves or individual positions on shelves are unequipped and it is necessary to avoid the waste of time which would result from interruptions in the routine test cycle. Such cases are dealt with as follows:—

(*a*) *Unequipped shelves.*

No access switch is fitted. Wiring only is provided on the same lines as the main items. The routiner is stepped past the shelf by means of a " busy " condition placed on the relative outlet of the previous rank of switch.

(*b*) *Unequipped positions.*

" Step over " facilities are provided only when a position on a shelf is vacant as part of the design of the exchange.

If a switch is removed, temporarily, for maintenance purposes the relative outlet on the access switch is not " busied " because it is preferable to allow the routiner to give an alarm when it reaches this position, thus constituting a reminder as regards the need for early replacement of the switch. When a switch has, unavoidably, to be removed for a considerable period it is desirable to preserve the sequence by taking a switch from the end of the group and fitting it in the vacant place. In such an event, the routiner gives a " switch busy " alarm on the last unoccupied position instead of the " routine finished " alarm. The " busying " of outlets on routiner switches in the case just mentioned is not recommended because of the danger of overlooking " unbusying " when the switch is replaced.

*Range of tests covered.*

(25) It is important that the tests performed by the auto routiner should have as wide a range as possible, provided that the cost of the routiner is not thereby made excessive or that circuit difficulties are not introduced.

In order that requirements can be ascertained it is necessary to :—

(*a*) Dissect the circuit of the item to be tested and prepare a list of the functions.

(*b*) Decide whether the functions can best be tested by simulating normal working conditions or whether it is necessary to gain access to additional points in the circuit and test it in piecemeal fashion.

(*c*) Decide whether all the functions can be covered and, if not, which functions (obviously relatively unimportant) may be left uncovered. These latter have to be dealt with by means of supplementary manual tests and therefore it is very desirable that the whole range of functions should, if possible, be covered. Failing this, the methods of performing the supplementary tests should be clearly in mind before the routiner circuit is proceeded with.

(*d*) Arrange the tests in the most suitable sequence in order to avoid undue complexity in the routiner circuit.

*Test of transmission elements.*

(26) If a transmission element comprising condensers, etc., is present, the question of the means to be adopted for

testing arises. To make an automatic test in terms of standard transmission units necessitates the use of amplifying valves and delicate measuring devices. Such a scheme is very costly and, in the author's opinion, cannot be justified for inclusion in " day to day " routine testing. Even if precise measurement is abandoned and the mere receipt of a tone (transmitted through the element) is checked, amplifying equipment is still required which adds greatly to the maintenance charges on the routiner.

(27) The method adopted by the British Post Office, in the absence of a better one, is to test each side of the transmission circuit, separately, by means of ringing current fed over the circuit, receipt being checked on a ringing relay. This, of course, is not a quantitative test and has the obvious disadvantage that the battery feed elements and condensers are not definitely tested.

*Severity of tests.*

(28) The tests imposed should not be too severe, otherwise the routiner will indicate switches as faulty which are still capable of giving a good service. The standard should be such that it is a little more onerous than the worst condition encountered in practice. Thus a switch will be shown as faulty before it has affected the service, but a maximum period of usefulness will have been obtained. Faulty apparatus should, when adjusted, be subjected to a test considerably more onerous than that imposed by the routiner.

*Check of slow relays.*

(29) It is essential that the routiner should check the releasing lags of important relays, such as those which guard the " private " on release. If more than one relay in a circuit has this function under differing conditions, every endeavour should be made to differentiate between the relays concerned. The timing need not be precise and it will suffice if the relays are proved to be correct within certain specified limits. A rotary line switch, stepped, when required, at 20 impulses per second, is a convenient method of achieving this, thus providing time intervals of 50 milliseconds.

*Pulse circuits.*

(30) Earth pulses of various frequencies are required on an auto routiner for purposes such as indicating a switch which has remained busy for an abnormal period. It is

important that the source of the pulse scheme be reliable, *e.g.*, an electric clock or ringing machine interrupter. Rotary line switches, stepping constantly at comparatively high speeds, should be avoided because of speed variation and the abnormal wear.

*Guarding by routiner.*

(31) Once the routiner has taken a switch for test it must prevent intrusion by normal calls. It is necessary to accomplish this and at the same time avoid unguarded intervals, particularly when the routiner guarding earth has to be removed in order to test whether earth is received from the switch.

(32) It is also important that guarding should be effected between tests under " continuous routine " conditions, otherwise the switch may be taken for a normal call. To achieve this, a " busy " test on the switch should be made *only* at the commencement of the test. Between successive tests, whilst the routiner apparatus is restoring, the " private " of the switch should be guarded.

*" Busy Ahead " scheme.*

(33) Auto routiners are usually arranged to " camp " on a busy switch and give an alarm if the switch remains busy beyond a normal period, as shown below :—

Directors, coders and senders—30 to 60 seconds.
Auto first code selectors } 3 minutes.
C.C.I. relay sets }

During the development stage a scheme was tried in which one switch was under routine test and at the same time the next switch was held " busied " in order that a test of this succeeding switch could proceed without delay.

(34) The only advantage of the " busying ahead " feature appears to be the possible reduction in time of a complete routine test cycle. In practice, however, after the first switch has been passed there is, generally, little time lost in waiting for busy switches to become free. This possible saving of time is of material value only when the normal holding time of a switch is comparatively long, say, three minutes. As regards switches with short holding times, the short wait, if any, although it is cumulative over a routine test cycle, is of no consequence. Further, the advantage applies only when routining is carried out during periods of

reasonably heavy traffic. If the routining is effected at night or during slack hours, the number of switches found " busy " and the consequent waits by the routiner will be negligible. With continuous attendance in operation at exchanges having over 3,000 lines it should be possible to carry out routine tests during slack periods. At small exchanges without continuous attendance it may not be possible to carry out all auto routining during periods of very slack traffic. In such circumstances "busying ahead" might enable the routine test cycles to be speeded up slightly; but such speeding up should not be needed, because the number of items to be tested is small and, with automatic routining, tests on the different items can proceed simultaneously.

(35) The disadvantages of " busying ahead " are:—

(*a*) If a routine test is carried out at times other than when the traffic load is light, the fact that two switches are held whilst only one is being tested, means a loss of traffic capacity.

(*b*) An extra level, with consequent increased cost, is required on the access switch.

(*c*) On " bottle neck " items such as directors, coders and senders, where the holding time is short, and particularly when a " clear down " time pulse is fitted, the inclusion of the " busying ahead " feature makes the initial " busy " test by the routiner less efficient from the point of view of ascertaining whether the switch clears down in the correct period after performing its functions in a normal manner. In other words, a switch may be slow in clearing down after use on a normal call and still not be indicated as faulty by the routiner because it releases during the time taken to test the previous switch, (which, in the case of a director, is, say, 60 seconds) plus the time delay period, 30 to 60 seconds, before the routiner " ' switch busy ' alarm " is given.

(36) Item (*c*) is not serious, however, because any switch which is slow in restoring, thus causing loss of traffic capacity, should be discovered when the auto routiner proceeds to test the switch, provided that the routine test is of such a nature that the switch has to be operated and released more than once.

In all the circumstances, it would appear that the " busy-

ing ahead " feature is of doubtful value and not worth the additional cost.

*Automatic search versus stepping keys.*

(37) It is necessary to step the access switches to a particular position when it is required to continuously routine a certain switch or continue a routine test cycle which has been suspended temporarily. Two methods of achieving this are :—

(*a*) By means of non-locking keys capable of stepping the access switches one step at a time. If necessary, these may be supplemented by other keys providing direct access to particular distributors, thus shortening the stepping operations.

(*b*) By installing, on the routiner, one jack or key per switch. When the jack or key is used, the routiner access switches are caused to hunt and to come to rest on the outlet leading to the required switch.

(38) Method (*a*) is quite satisfactory when a small number of switches are concerned. For larger groups of switches it is less satisfactory, and there is a danger of passing the required switch unless a close watch is kept on the access switch indicating lamps.

(39) As regards (*b*) it may be said that the scheme is somewhat complicated and costly both as regards apparatus and cabling. In cases where it might be of most value, *i.e.*, when a large number of switches, say, over 1,000, are concerned, the cost becomes almost prohibitive.

(40) It would appear, therefore, that method (*b*) cannot be justified for large groups and is certainly not required for small groups of switches.

*" NU " tone on test numbers.*

(41) It is sometimes necessary to make use of numbers in the exchange series for testing purposes, these numbers being allocated, permanently, for routining. The aim should be to employ numbers of such a character that the likelihood of the test number being reached by the public is reduced to a minimum. If such a plan is not feasible it is desirable to arrange for " NU " tone to be placed on the test circuit. This is easy to apply when the routiner is not in use, but, if the tone is likely to interfere with the routiner tests, it becomes more difficult. Hence the need to select " out of reach "

numbers. This raises the point regarding the desirability of having switches with 11 levels so that a spare level, quite apart from the exchange numbering scheme, is available for routine testing purposes.

*Meters.*

(42) When switches having traffic recording meters are taken into use for routine test purposes it is necessary to have some indication as to the amount of this artificial traffic, and, therefore, a meter should, if required, be connected to the routiner to register the number of times the switches have been taken into use. The meter should be arranged to operate once each time a switch has been tested and released.

*Fault imitation keys.*

(43) These are provided to check the more important functions of the routiner, as otherwise it would be necessary to render switches faulty in order to verify that the routiner was capable of performing its various tests satisfactorily. A " busy test " fault imitation key is essential in this connection because, if this feature was out of order, there would be a danger of the routiner commencing to test on switches already engaged on normal calls, thus causing serious interference with the service. Other than by the fault imitation keys no attempt is made to prove that the routiner is functioning correctly, as an intelligent user can soon detect trouble.

*Test cancel keys.*

(44) As an auto routiner makes tests of practically all the functions of a switch it is desirable that tests of some of the functions, which are not of vital importance, can be eliminated when desired. The need for test cancel keys arises in the following typical cases :—

(*a*) It may be desirable, during a normal routine test cycle, to perform some tests more frequently than others. The cancel keys enable this to be done and the test on a group of switches is therefore speeded up.

(*b*) When a maintenance officer has a particular switch under continuous routine and has proved that the minor functions are " O.K." but he desires to continue the other tests, such functions as " time pulse releases " may be eliminated, thus reducing the time required to deal with the switch.

*Alarm scheme.*

(45) Faults discovered by a routiner are brought to notice by the glowing of a lamp to indicate the function which has failed; also by the sounding of a local audible alarm. As the routiner is normally unattended this alarm should be extended to the exchange main alarm scheme. For occasions when the routiner is attended, because of its use on a particular switch, a " main alarm cut off " key should be provided. When the main alarms are segregated into " prompt " and " deferred," the routiner fuse and magnet alarms should be connected, permanently, to the former and all other alarms to the latter under control of the key.

*Arrangement of apparatus on the routiner.*

(46) The operating keys and indicating lamps should be mounted near the centre of the routiner, *i.e.*, at such a height as to be operated conveniently by a maintenance officer standing erect.

(47) All apparatus should be of robust construction, of minimum fault liability and readily accessible for maintenance purposes. The rotary line switches which control the tests, and are therefore in almost constant use, should be of the " heavy duty " type. They should be provided in duplicate or, alternatively, arranged so that replacements can be carried out speedily.

(48) When the received digits are checked by the routiner, a display is provided and the digits are displayed for about four seconds. Although this display panel is not essential when the routiner is functioning automatically and the received digits are " O.K.," it is of great service when wrong numbers are received. In such cases it is necessary for the maintenance officer to be aware of the actual digits received, thus furnishing a clue to assist in the diagnosis of the fault.

(49) As regards the relative arrangement of the display lamps and keys it is desirable that they be closely associated, thus ensuring that the received digits are easily read and checked at a glance against the particular " Digit set up keys " operated.

*Location of Auto Routiners.*

(50) Because a routiner is automatic in action it may be said that its location, relative to the plant tested, is immaterial.

It has even been suggested that all routiners should be located together, perhaps in a separate room, and the control centred there in the hands of one official whose sole responsibility would be to keep the routiners in operation and report switch faults as they were disclosed. The objections to such a suggestion are as follows:—

(*a*) The routining officer has no immediate interest in the plant routined and is not an expert as regards the troubles experienced and the methods of removal—although a routiner is automatic in action, it demands intelligent use, as it does not always indicate a fault precisely but rather the failure of a function which may be caused by any one of a number of faults.

(*b*) There may be a considerable interval between the time the fault is detected and the time it is reported to the maintenance officer who is to remove it.

(*c*) In addition to performing routine tests whilst "unattended," the use of a routiner is required by a maintenance officer in certain circumstances, particularly in the case of wrong displays, as an aid in fault diagnosis. In such cases the maintenance officer may have to place certain conditions on the switch in trouble and check the results as disclosed by the routiner.

(*d*) The further a routiner is placed away from the items to be tested the greater the cost of the permanent cabling.

(51) It would appear, therefore, that a routiner should be located as close as possible to the plant to be tested and, to achieve the best results from a maintenance point of view, should be available for use by the maintenance officer responsible for the plant.

*Remote control of "Reset" feature.*

(52) It has been stated (paragraph 11) that it is sometimes desirable for a maintenance officer to watch a switch in operation when locating a difficult fault. This is provided for by fitting jacks, in multiple, on the switch racks. By means of a cord fitted with a pear push, connection can be made *via* a jack to the routiner circuit which controls the feature of restarting the test on a particular switch. When it is desired to bring this facility into operation the maintenance officer operates the "continuous routine" key on the

routiner, steps the access equipment to the desired switch and starts the routiner functioning. The routiner will thus continue to test the particular switch, test after test, until a fault is disclosed or the routiner is stopped. The maintenance officer observing the switch has full control, and when the routiner stops on account of a fault he can restart the test as often as desired in order to watch the progress of operations and so locate the trouble.

*Combination of routiners on one rack.*

(53) In order to save floor space it is sometimes desirable to accommodate more than one routiner on the same rack. Such a scheme has limitations because of the possibility of congestion near the routiners and of the length of cabling; and it is generally not economical to have more than two routiners on the same rack. In such a case, the plant tested by two routiners so assembled should be definitely associated, *e.g.*, C.C.I. relay sets and coders, key sending " B " positions and senders, so that either routiner will be reasonably near the apparatus under test.

The method of mounting two routiner equipments on one rack should be such that a vertical line of demarcation results. All the equipment for one routiner should be on the left hand side of the line, and on the right hand side for the other routiner. As regards panel equipment, this is easily arranged because the stile strip provides a dividing line, but on other portions of the rack, particularly where relays are concerned, a blank space should be left on the mounting plate to provide the dividing line. Alternatively a white line should be painted on the mounting plates.

*Two routiners for a large group of switches.*

(54) When a group of switches is very large and so important that a daily test is essential, two routiners may be necessary to carry out the tests. The best way of connecting the routiners is to divide the plant into two portions and allocate one routiner to each position. The routiners may be located side by side or separated in accordance with the lay-out of the plant, and arrangements may be made, if thought necessary, for either routiner to be capable of routining the whole of the plant. This can be accomplished by fitting a " Routine extension " key at the top of each routiner. Assuming the key on No. 1 routiner to be operated, the conditions are as follows:—

(*a*) No. 1 routiner, on being started, routines its own equipment in the normal manner, but when the end is reached, a relay operates which changes over the routiner test leads to No. 2 routiner's access equipment, and the test continues on the second half.

(*b*) A red lamp is caused to glow to indicate that the conditions are as in (*a*).

(55) It is of course possible to step No. 1 routiner past the first half of the equipment and proceed at once to test the second half.

Fault indication is given on the routiner in use, but access switch indication is shown in a normal manner on the relative routiner even when the extension key is operated.

## USE AND MAINTENANCE.

*General.*

(56) To obtain the best service from an auto routiner, intelligent use is demanded. The routiner is provided to bring to the notice of the staff, apparatus which is not functioning correctly or is approaching the stage of inefficient functioning. The indication furnished is merely that a certain function, or functions, is not correct and this may be caused by one of several faults. It is therefore necessary for the fault to be taken in hand and located precisely. The usual means should be adopted to this end, and when the fault is removed, it may, or may not, be necessary to use the auto routiner to check the correct condition.

(57) As regards relay adjustments, these should be carried out by means of a separate test set and in accordance with the specified value for " readjustment." It should be remembered that, generally, the routiner does not impose these " readjust " conditions and therefore mere retest by the routiner, even if the switch is passed as " O.K.," does not prove that a relay has been adjusted in such a manner as to ensure that it will remain in correct adjustment for as long a period as possible.

*Routiner faults.*

(58) In view of the importance of an auto routiner and the desirability of maintaining it in constant service, only thoroughly competent officers should be allowed to remove any faults which may occur. The fault record should be in

the nature of a life history and furnish full particulars of any failures, *e.g.*, the date, period of time out of use, and reason.

*Operating instructions.*

(59) Brief instructions as regards the manipulation of the routiner keys should be displayed on, or near to, the routiner in order that officers other than those normally on the duty, may operate the routiner when necessary.

(60) For items such as directors which provide translations for the different codes dialled, it is essential that the routine tests should cover all the codes and translations. It is therefore necessary to so arrange the routine tests that a different code is used on each test.

As regards the numerals, it is advisable to ring the changes on these also. The following table shows a suitable order of test :—

1 2 3 4
2 3 4 5
3 4 5 6
4 5 6 7
5 6 7 8
6 7 8 9
7 8 9 0
8 9 0 1
9 0 1 2
0 1 2 3

When preparing routine test charts the routines specified should cover such matters as the above.

*Correct use of test cancel keys.*

(61) In connection with test cancel keys (paragraph 44), it is essential that the facilities for eliminating tests be used with discretion, otherwise the functions of the routiner will be seriously interfered with. Normally, few, if any, of the test cancel keys should be operated under general routine conditions : their main use is when making repeated tests on a particular switch.

*Interpretation of access switch lamps.*

(62) Lamp indication as regards the particular switch under test may be furnished by three rows of lamps :—

(*a*) To indicate the rack, board or unit.
(*b*) The shelf on the rack.
(*c*) The particular switch on the shelf.

The above information is a positive indication of the position of the switch under test.

(63) If, however, a large number of items arranged consecutively in numerical order is concerned, the above scheme cannot apply, and it is of course not economical to have individual lamps per item. For such a case (a large group of outgoing junctions, say some thousands, is a typical one) a card record is necessary in order to correlate the access switch lamp indication to the particular junction under routine. Thus, when only one strip of 20 lamps, under the control of a key, is employed in connection with the outlets of all the access equipment, the conditions when the routiner stops and indicates a fault might be as shown in the following table :—

| Position of Lamp Control Key. | Indications furnished by lamps. | | Particular lamp of the 20 which glows. | Remarks. |
|---|---|---|---|---|
| | Outlet From | To | | |
| 2nd Position | Primary Distributor | Secondary Distributor Switch in use | 3 | Primary Distributor has passed 2 outlets 2×20×20 = 800 |
| 1st Position | Secondary Distributor | Access Switch in use | 5 | Secondary Distributor has passed 4 outlets 4×20 = 80 |
| Normal | Access Switch | Junction under test | 12 | Access switch is stood on 12th outlet = 12<br>Total ... 892<br>*i.e.*, 892nd junction in sequence is under test. |

A note would be made in the form " 3—5—12 " and, on reference to a card record, the particular junction concerned could be ascertained.

*Writing Desk.*

(64) A small writing desk should be fitted on each routiner, at a convenient height for writing upon when a person is standing, in such a manner that access to the equip-

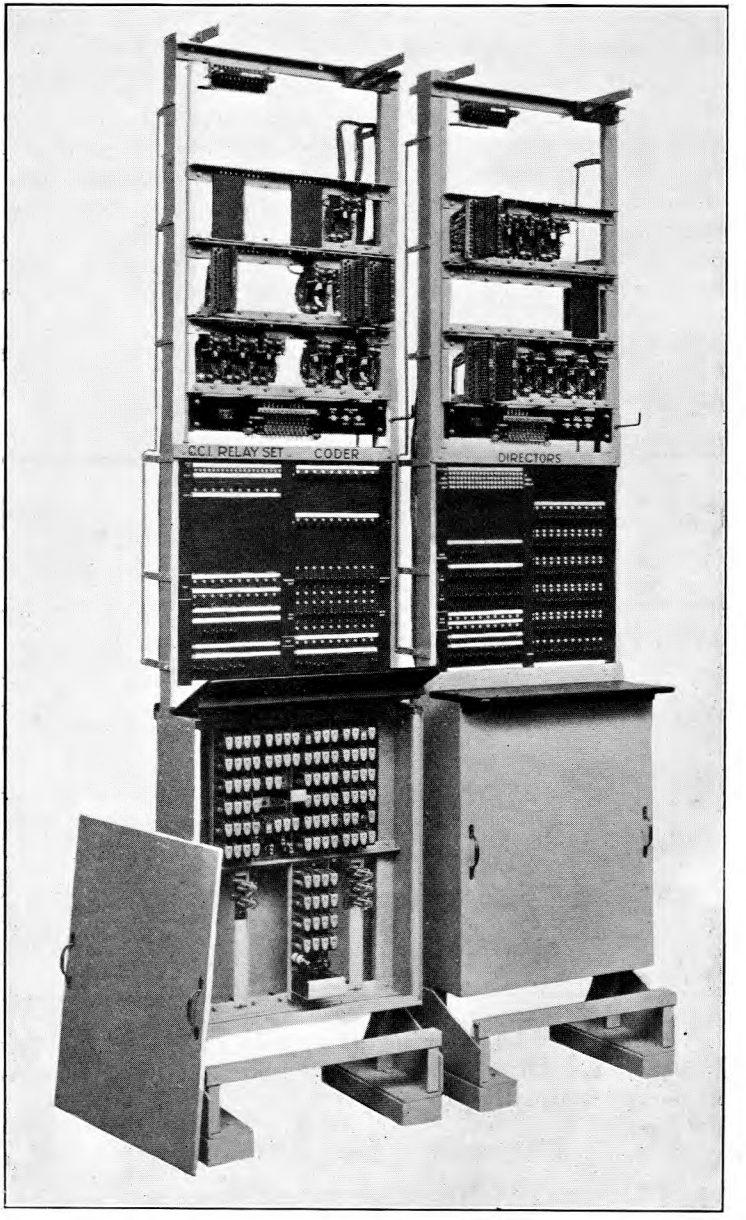


FIG. 2.—TYPICAL ROUTINERS (showing two Routiners on one rack).

ment is not impeded. The desk is required to accommodate dockets for recording faults. When an alarm is received from a routiner showing that a fault has been disclosed, the maintenance officer who answers it may verify the presence of a fault by operating the " Re-set " key thus causing a re-test of the same switch. He should then record details of the fault on a docket for attention and step the routiner past the faulty switch in order that the routine test cycle may continue.

## COST COMPARISONS.

(65) To arrive at the financial aspect of auto routining it is necessary to make a comparison with manual routining. This may be done by comparing " full automatic " routining with either " manual " routining or " semi-automatic " routining. A brief definition of these terms follows :—

*Manual routining.*

(66) Portable tester moved from switch to switch, connected by means of a plug and cord. Each test set up separately by operator throwing keys.

*Semi-automatic routining.*

(67) Portable tester moved from switch to switch, connected by means of a plug and cord. Test of one switch performed automatically when the operator starts the tester.

*Full automatic routining.*

(68) Tester not portable. Connects with each switch in sequence, and performs all tests, automatically.

(69) It would appear to be unfair to compare full automatic with manual routining for the more important items of director equipment, because it is obvious that when the number of switches and also the functions to be tested are great and the testing has to be carried out at frequent intervals, a machine can perform tests far quicker than a man can operate keys and note the progress of the various tests. Thus the annual charges on the capital cost of the auto routiner are far outweighed by the excessive labour cost of operating the manual routiner. If, however, only a few functions have to be tested at comparatively infrequent intervals the position may be reversed.

(70) In order to make a comparison between full automatic and semi-automatic routining it is necessary to examine the factors relating to the two schemes :—

| | CAPITAL COSTS. | | MAINTENANCE COSTS. | |
|---|---|---|---|---|
| | FULL AUTO. | SEMI AUTO. | FULL AUTO. | SEMI AUTO. |
| (*a*) Apparatus required to perform the tests (Apart from means of access). | A full auto routiner accomplishes a routine test cycle in a shorter time than a semi-auto routiner because shifting from switch to switch is avoided. With a large number of switches two semi-auto routiners may be required when one auto routiner will sufficice. *(No allowance made for this and costs assumed to be equal).* | | Apparatus mounted on a portable tester has a higher fault liability than when mounted permanently on a rack. Relative labour cost figures for maintenance may be taken as :— 4 | 5 |
| (*b*) Means of access. | The access switches, rack space and cabling constitute a heavy charge against the full auto routiner. | Access by means of a switch jack may mean more jack points than would be required with a full auto routiner. *(No value is assessed for this).* | The access switches are stepped mainly in single steps and their fault liability is therefore low. | The cords and plugs necessary for manual access constitute a comparatively high fault liability. |
| | | | *(Maintenance costs assumed to be equal).* | |

| | CAPITAL COSTS. | | MAINTENANCE COSTS. | |
|---|---|---|---|---|
| | FULL AUTO. | SEMI AUTO. | FULL AUTO. | SEMI AUTO. |
| (*c*) Labour required to carry out a test on a group of switches. | — | — | Attendance normally required only at start and finish of test cycle, say 4 mins. in all. (Attendance for faults covered in (*d*) ). *With full auto routiner the plant may be placed under more or less constant routine with practically no additional cost. (No allowance made for this).* | Continuous attendance needed and period is lengthy because of the necessity to move the tester from point to point, also the need to mount and descend steps to connect tester also start and stop it. If switches are busy, waiting occurs or a record has to be made and another attempt made later. It is estimated that even with strictest application to duty, the average time between successive tests cannot be less than 30 seconds. Impeding access to switches for other purposes is another factor which might be given a value. *(No allowance has been made for this).* |
| (*d*) Recording of faults and subsequent removal. | — | — | *(Costs assumed to be equal).* | |
| (*e*) Stores. | — | — | For actual routiner the costs are equal. For Full Auto access switches there is a small charge but this is more than offset by the cost of renewals on plugs and cords for manual access. *(Costs assumed to be equal).* | |

(71) It will thus be seen that without assessing values for the minor features the case is practically a direct comparison between the annual charges on the capital cost of access switches, and the labour charges consequent on manual access. The application of such a scheme of comparison cannot be said to be biassed in favour of automatic routining because no allowance has been made for the points mentioned which although difficult to assess in £ s. d. have nevertheless some value.

(72) Let A = Annual charges on access equipment for full auto routiner.
M = Annual maintenance cost of full automatic routiner (access equipment being ignored).
$M_1$ = Annual maintenance cost of semi-auto routiner.
L = Labour cost for one cycle of routine tests on switches concerned using full auto routiner.
$L_1$ = Ditto using semi-automatic routiner.
N = Number of test cycles per annum.

The comparison therefore becomes :—

| *Full Auto.* | | *Semi-Auto.* |
|---|---|---|
| $A + M + (L \times N)$ | compared with | $M_1 + (L_1 \times N)$ |

I have calculated cases on this basis and it is an easy matter to justify auto routining for important groups of plant which need a daily test, *e.g.*, if a case of 50 director switches is taken the saving in annual charges is £212.

When, however, items of plant which are of less importance and which are tested monthly, quarterly or six monthly, are considered, it is much more difficult to justify auto routining because $L_1$ and N are very small and cannot offset the large cost of A. It is therefore necessary to assess values for the other factors mentioned in the comparison.

## CONCLUSION.

(73) It was stated at the commencement that automatic routiners are in their infancy. The truth of this statement is realised more and more each day by those engaged on the designing work, and if this paper results in useful suggestions being obtained it will have achieved its object.

As the art of automatic telephony develops there would appear to be no limit to the possibilities of producing machines to perform routine testing duties of any magnitude. Care should, however, be taken to avoid overstepping the mark and carrying out frivolous tests. If kept within reasonable limits and based on sound economic grounds the writer is of the opinion that in future years, when the history of automatic routiners is written fully, it will be found that they have been one of the main features which have permitted complex automatic telephone exchanges to be operated in a satisfactory manner.

# APPENDIX I.

GENERAL LIST OF MAIN KEYS AND THEIR FUNCTIONS.
(L) indicates " Locking " type and (NL) " Non-Locking."

| KEY. | Function. |
|---|---|
| START (L.) | Starts automatic stepping of routiner access switches, as required, in order to connect routiner to first switch in group under test. Disconnects all homing circuits. |
| CONTINUOUS ROUTINE (L.) | Prepares the stepping circuits of access switches for manual operation from " stepping " keys. Causes an *individual* switched to be routined, continuously, when the " start " key is operated. The routine continues until it is stopped either by a fault or by the restoration of the " Start " key.<br>A test of the " busy " condition of the switch is made on the first test cycle only, the busy test being ignored on subsequent tests.<br>The switch under test is guarded during the interval between the completion of one test and the commencement of the next. |
| DISTRIBUTOR SELECTING (N.L.) | Provides access to a particular distributor for manual stepping purposes, thus shortening the number of stepping operations required to gain access to a particular switch. |
| *STEP ON (N.L.) | Breaks alarm circuit.<br>Restores the test switch, steps access switch to next switch in group under test and re-starts the routine. |
| *RESET (N.L.) | Breaks alarm circuit.<br>Restores test switch and re-starts routine on same switch |
| ACCESS SWITCH STEPPING (N.L.) | Alows access switch to be stepped manually (used in conjunction with " Continuous Routine " key). |
| DISTRIBUTOR STEPPING (N.L.) | Allows distributor switch to be stepped manually (used in conjunction with " Continuous Routine " and " Distributor Selecting " keys). |
| MAIN ALARM (L.) | When operated opens the main alarm, but leaves local alarm in circuit Does not break the " fuse " and " release " alarms which are connected permanently to the " prompt " main alarm system. |
| "F.I." KEYS (L.) | Fault imitation keys as required which, when operated, simulate certain switch fault conditions in order to prove that under these conditions the routiner will stop and give an alarm. |
| CANCEL TEST (L.) | Certain tests such as " forced release " may be cancelled as required in order to speed up a routine test cycle. Used mainly in connection with a continuous routine test when faulty operation of a certain function is suspected and it is known that other functions are operating correctly. |

* These keys when used should be held in operated position for at least two seconds in order to allow time for the testing apparatus to restore to normal.

# APPENDIX II.

## LIST OF AUTOMATIC ROUTINERS IN OPERATION, UNDER CONSTRUCTION OR CONTEMPLATED.

| Item | Routiner. | Access Switch Points. | Brief description as to method of test. Also whether common equipment is concerned. | Average time occupied on a test. Assuming not busy and no faults. | In operation. Under construction or contemplated. |
|---|---|---|---|---|---|
| 1 | Auto 1st Code Selector. (Also incoming 1st code selector if required. (100 outlets). | —<br>+<br>P<br>Meter<br>"K" Relay | Code " M.M.M." sent via 1st Code Selector and "A" digit switch into Director. Director sends out translation to route call back to routiner via a spare 2nd or 3rd code selector level.<br><br>Common equipment concerned is "A" digit switch Finder, "A" digit switch and Director. | Complete test including forced release ... 160 secs.<br>With either of forced release tests cancelled 90 ,,<br>With both of forced release tests cancelled 30 ,, | In Operation. |
| | Director | —<br>+<br>P<br>Pulse | Input code and numerals also output code translation set up on digit keys.<br>Impulses sent into Director. Receipt of correct code translation and numerals checked automatically. Display panel fitted.<br>No common equipment concerned. | Complete test with 6 digit translation ... 90 secs.<br>With forced release test cancelled ... 30 ,,<br><br>With forced release also either series or shunt tests cancelled ... 18 ,, | ,, ,, |
| 3 | Coder. (Early types). | —<br>+<br>P<br>Pulse | Digits 4444 and 8888 or 4848 and 8484 impulsed into Coder. Received impulses checked automatically.<br>Display panel fitted.<br>No common equipment concerned. | 27 secs. | ,, ,, |
| • 4 | Coder (P.O. standard). | —<br>+<br>P<br>Pulse | Any digit set up on keys as required and impulsed into Coder. Received impulses checked automatically.<br>Display panel fitted.<br>No common equipment concerned. | 15 secs. | ,, ,, |

[*Continued*

LIST OF AUTOMATIC ROUTINERS IN OPERATION, UNDER CONSTRUCTION OR CONTEMPLATED.

| Item. | Routiner. | Access Switch Points. | Brief description as to method of test. Also whether common equipment is concerned. | Average time occupied on a test. Assuming not busy and no faults. | In operation. Under construction or contemplated. |
|---|---|---|---|---|---|
| 5 | C.C.I. Relay Set. (Early types). | — } In<br>+ }<br>— } Out<br>+ }<br>P }<br>H.A. Relay | Digits 1111 impulsed via relay set and coder finder into Coder.<br>Receipt of 4 impulses checked automatically on relays.<br>No display panel.<br>Common equipment concerned is Coder. | 10-15 secs. | In Operation. |
| 6 | C.C.I. Relay Set. (P.O. Standard). | — } In<br>+ }<br>— } Out<br>+ }<br>P }<br>H.A. Relay | | 15-20 secs. | ,, ,, |
| 7 | Sender (4 digit). | W<br>X<br>Y<br>Z<br>Start<br>Busy hold | Digits set up on keys and impulses sent into sender.<br>Received digits checked automatically.<br>Display panel fitted.<br>No common equipment concerned. | 15 secs. | ,, ,, |
| 8 | Sender (7 digit). | W<br>X<br>Y<br>Z<br>Start<br>Busy hold | Strowger and C.C.I. pulses catered for.<br>Code and numerals set up on digit keys as required. Code translation and numerals checked automatically.<br>Display panel fitted.<br>No common equipment concerned. | 15 secs. (C.C.I. Call)<br>20 secs. (Strowger call) | |

[*Continued*

LIST OF AUTOMATIC ROUTINERS IN OPERATION, UNDER CONSTRUCTION OR CONTEMPLATED.

| Item. | Routiner. | Access Switch Points. | Brief description as to method of test. Also whether common equipment is concerned. | Average time occupied on a test. Assuming not busy and no faults. | In operation. Under construction or contemplated. |
|---|---|---|---|---|---|
| 9 | Keysending " B " Position. Relay Sets (Tandem Exchange) | —<br>+<br>Assignment.<br>Junction lamp<br>4 Digit Key leads<br>Oprs. Battery }<br>Feed Relay } | Generally, position must be unstaffed to allow routine to commence.<br>Code "XXA" plus numerals impulsed via sender finder into sender.<br>Strowger pulses, as a translation, are received and used to route call back to routiner via a spare level on a third Tandem selector.<br>Common equipment concerned is Sender and Junction Finders, Sender and Code selectors. | One trunk relay group ... 35 secs.<br>One position with 40 junctions ... 24 mins. | In Operation. |
| 10 | Keysending " B " Position. Relay Sets (Director Exchange) | —<br>+<br>Assignment.<br>Junction lamp<br>Oprs. Battery }<br>Feed Relay }<br>4 Digit Key leads | Generally, position must be unstaffed to allow routine to commence.<br>" 0098," or other suitable digits, are pulsed via sender finder into Sender. Impulses received from Sender route. call back to routiner via a final selector.<br>Common equipment concerned is Sender Finder, Sender, Numerical and Final Selectors. | One trunk relay group ... 35 secs.<br>One position with 40 junctions ... 24 mins. | " " |
| 11 | Tandem Exchange C.C.I. Relay Set | + } In<br>— }<br>— } Out<br>+ }<br>P<br>H.A. relay | Digits 1111 impulsed via relay set and coder finder into Coder. Receipt of 4 impulses checked automatically on relays. No display panel fitted.<br>Common equipment concerned is Coder. | 15 secs. | " " |

[*Continued*

LIST OF AUTOMATIC ROUTINERS IN OPERATION, UNDER CONSTRUCTION OR CONTEMPLATED.

| Item | Routiner. | Access Switch Points. | Brief description as to method of test. Also whether common equipment is concerned. | Average time occupied on a test. Assuming not busy and no faults. | In operation. Under construction or contemplated. |
|---|---|---|---|---|---|
| 12 | Tandem Auto to Auto Relay Set | —, +: In<br>—, +: Out<br>P<br>H.A. relay D | Digit 9 impulsed into relay set 4 times under various conditions. Receipt of repeated impulses of "good ratio" checked automatically on a selector embodied in the routiner.<br>No common equipment concerned. | 25-30 secs. | Under construction. |
| 13 | 11/20 P.B.X. Final Selector | —, +, P: In<br>$P_1$<br>$P_2$<br>Rot. Mag. | Two test lines, one normal and one auxiliary, in "90" position of selector are used to route calls back to the routiner. Digit "9" impulsed into selector several times and various functions checked.<br>No common equipment concerned. | 30 secs. | ,, ,, |
| 14 | Over 20 P.B.X. Final Selector | —, +, P: In<br>P Wiper., D.M.: R.L.S. | Last working line used to route calls back to routiner. R.L.S. given one impulse to start rotary search. Repeated several times to prove various functions.<br>No common equipment concerned. | 15 secs. | ,, ,, |
| 15 | Junctions O/G from Auto Exchange to C.C.I. Exchanges. (This Routiner will also test junctions O/G to auto exchanges, by employing "General" test only). | —<br>+<br>P | Two tests can be performed. "General" test when all free junctions are tested for continuity and reversal without calling C.C.I. Exchange.<br>"Group" test when a group of junctions to a particular exchange is tested by calling C.C.I. operator. | General Test ... 3 secs.<br>Group Test ... 9 secs.*<br>* Period between "Marker Pilot" and appearance of display is 1½ secs.<br>Period of 9 secs. assumes that C.C.I. operator answers immediately. | In Operation. |

[*Continued*

LIST OF AUTOMATIC ROUTINERS IN OPERATION, UNDER CONSTRUCTION OR CONTEMPLATED.

| Item. | Routiner. | Access Switch Points. | Brief description as to method of test. Also whether common equipment is concerned. | Average time occupied on a test. Assuming not busy and no faults. | In operation. Under construction or contemplated. |
|---|---|---|---|---|---|
| 16 | Auto 1st Code Selector (200 Outlets) | — + P In<br>— + M Out<br>K Relay. | | | Contemplated. |
| 17 | Group Selectors (100 or 200 outlets) | | | | ,, |
| 18 | Ordinary or 2/10 P.B.X. Final Selectors (100 or 200 outlets). | | | | ,, |
| 19 | Straight Forward Junction Relay Sets. | | | | ,, |
| 20 | Straight Forward Junction "Outlet" Relay Sets. | | | | ,, |