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

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U.D.C. 621.316.9

The historical development of protective devices fitted at the exchange and at subscribers' premises is surveyed. Three devices, the fuse, the heat coil and the lightning protector, were adopted as standard about 1900 and remained in use, with minor modifications, for many years. These devices were not, however, entirely effective, and had a high fault liability. The changes introduced at various times in an endeavour to overcome these difficulties are discussed and current developments are described.

INTRODUCTION

IN the early days of British telephone development, i.e. before 1895, the only protective component normally fitted at both the exchange and subscriber's termination of a telephone line was a lightning arrestor. The most common form consisted of an earthed metal plate with saw-toothed edges placed against, but not touching, the straight edges of plates carrying the line terminations. In 1894, W. H. Preece, later to become Sir William Preece, Engineer-in-Chief, read a paper[1] before the Institution of Electrical Engineers, reporting on a visit he had made to the United States. He stated that protection from lightning and from the danger of fire caused by contacts with electric light and traction wires was obtained by providing all circuits with:

(*a*) a fine-wire fuse,
(*b*) an air-spaced carbon protector, and
(*c*) a heat coil which earthed the line when stray currents exceeded a certain strength.

It seems likely that the principal features of the system of protection then developed were as follows:

(*i*) A main element (the carbon protector) arranged to discharge excessive voltages.

(*ii*) A fuse, fitted between the main element and the external line, to limit the current through the main element to earth, it being considered that the relatively small protector would not withstand a prolonged discharge without risk of destruction. The fuse also protected exchange equipment.

(*iii*) A heat coil to protect internal equipment against small continuous currents which were not large enough to operate the line fuse but were of sufficient magnitude to damage exchange equipment.

Shortly after the presentation of Preece's paper, the three protective components mentioned above were adopted by the British Post Office for the protection of line terminations at its exchanges and at subscribers' premises. The actual components fitted at the ends of a line depended upon the degree of exposure of that line to lightning or power-circuit contacts, and the principles applied appear to have been that lightning protectors were provided if open wires were involved, heat coils and fuses were fitted for wholly underground lines and all three items were considered necessary if the telephone wires were overhead and run in the vicinity of overhead power wires.

Quite apart from protection at the exchange and subscribers' premises it was also the practice to fit fuses on either side of power crossings.

EARLY FORMS OF EXCHANGE PROTECTION

With the adoption of the fuse, lightning protector and heat coil about 1900, the telephone exchange main distribution frame (M.D.F.) was first evolved. Fuses were accommodated on the line side, and lightning protectors and heat coils were located on a unit fitted on the exchange side of the frame. The first type of fuse mounting (Fuse Mounting No. 4002) accommodated narrow glass fuses with slotted end-caps. These fuses were fixed in position by screws (Fig. 1). This type of mounting was superseded by Fuse Mounting No. 4001 (Fig. 2) in 1909.

Fuse Mounting No. 4001 was the standard fuse mounting for local-line pairs for 30 years. A higher standard of insulation resistance and more reliable contacts were, however, found necessary for trunk and junction pairs, and in 1926 Fuse Mounting No. 4028 (Fig. 3) was developed for use on such circuits. In 1939 it was decided that, because of insulation failures and occasional poor contacts with the barrel-ended fuse used on the Fuse Mounting No. 4001, the Fuse Mounting No. 4028 should also be used for local pairs.

So far as the exchange side of the M.D.F. was concerned, the lightning arrestors and heat coils were originally housed in a unit known as Protectors and Heat Coils 40B. This unit did not incorporate testing facilities, and although a unit with such facilities (the Protector, Heat Coil and Test, 40B—Fig. 4) was introduced in 1913,

† External Plant and Protection Branch, E.-in-C.'s Office.
[1] PREECE, W. H. Notes of a Trip to the United States and to Chicago—1893. *Journal I.E.E.*, Vol. 23, p. 40, 1894.

FIG. 1—ORIGINAL TYPE OF FUSE MOUNTING (FUSE MOUNTING NO. 4002)

it was not until 1936 that this item became the standard for the exchange side of the M.D.F. It is perhaps significant that the extensive failures of heat coils which now occur do not appear to have been in evidence before the inclusion of test facilities on the protector.

Components

The first fuses used in the Fuse Mounting No. 4001 were of the glass-tube type and were rated at 3 amp. However, there was a tendency to serious arcing at such fuses when power contacts occurred and the fuse was re-designed, the fuse wire being enclosed in a small-bore unglazed porcelain tube.

The lightning arrestors of the same period consisted of two small carbon blocks, with a fusible plug cast in the earthed electrode and so arranged that a heavy discharge

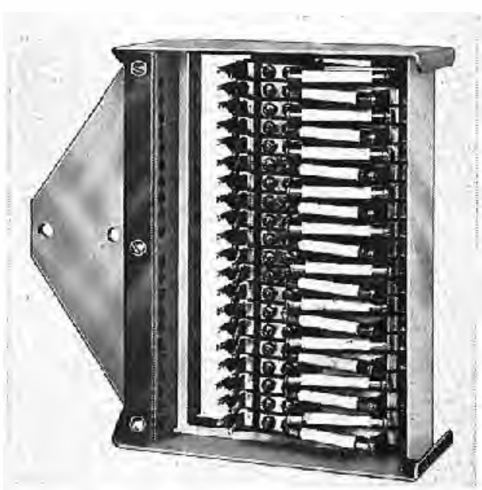


FIG. 2—FUSE MOUNTING NO. 4001

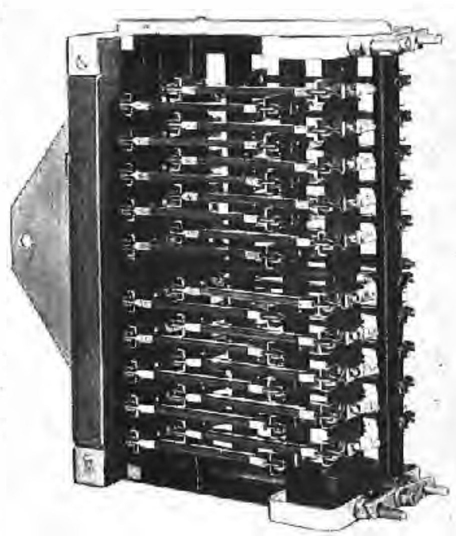


FIG. 3—FUSE MOUNTING NO. 4028

would melt the plug and put the line and earthed electrode into metallic contact.

The carbon blocks were separated by a mica sheet 3 to 4 mils thick, containing three $\frac{1}{8}$ in. holes as spark gaps. This arrangement was superseded by a similar device in which the fusible plug was omitted and the mica spacer replaced by a sprayed coating on the carbon.

The arrangement, characteristics and method of operation of the heat coil were virtually no different from those of its present-day counterpart.

Fault Liability

The three components so long used for protection purposes suffered from a variety of disadvantages. They were particularly susceptible to faults attributable largely

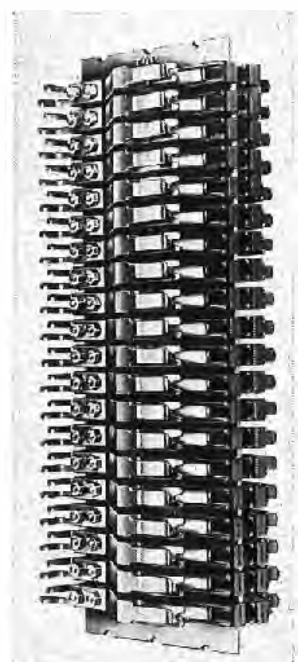


FIG. 4—EXCHANGE PROTECTOR UNIT (PROTECTOR, HEAT COIL AND TEST, 40B)

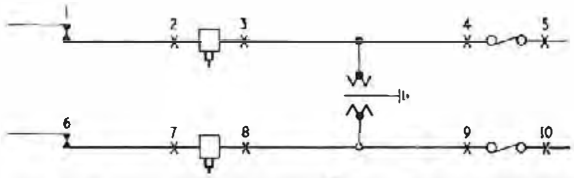


FIG. 5—SERIES CONTACTS INTRODUCED BY PROTECTIVE COMPONENTS

to the number of contacts (10—see Fig. 5) which they introduced in series with each pair of wires.

Although fuses were originally screwed into position, as shown in Fig. 1, clipped-in fuses were subsequently adopted, but they had the disadvantage of variable contact resistances. Furthermore, line-testing operations carried out from fuse mountings tended to distort the fuse springs, producing light spring-pressures and aggravating loose connexions.

The heat coil was also a source of faults. Spring pressures of protector mountings varied, and whilst this did not influence normal operation of the coil, it did affect the tendency of the fusible alloy to "cold flow," with consequent failure of the coils.

Originally, protection against excessive voltage was given by carbon protectors. These tended to disintegrate and cause short-circuits after a few discharges. Short-circuits were also caused when deposits of carbon dust formed between the electrodes. In addition, it was difficult to ensure uniformity of break-down voltage. The position improved when Protector-Electrodes No. 1B, described later, were introduced.

Although the combination of fuse, lightning protector and heat coil has served the Post Office well, the weaknesses described above have, over the years, resulted in several attempts at modification and some of the more important of these will be described.

PAST ATTEMPTS AT MODIFICATION OF PROTECTION

Apart from modifications to the design of fuse mountings, introduced mainly to secure a higher standard of insulation resistance and better contacts, little attempt appears to have been made to change protective arrangements until the early 1930s. It was then realized that the previously accepted methods of protection were not entirely satisfactory, particularly as an increasing proportion of line plant was being put underground.

The problem was investigated, and in 1934 it was recommended that a new protection technique, based on the following proposals, should be the subject of experiment:

(*a*) Fuses should be eliminated.

(*b*) Heat coils should be provided on all circuits.

(*c*) Lightning protectors should be fitted only to circuits having overhead conductors.

(*d*) All protective components should be on the line side, and test jacks should be fitted on the exchange side of a new-type M.D.F.

A prototype frame was installed at Worksop in 1938. The protective components were, in fact, all mounted in a withdrawable unit on the exchange side of the M.D.F. In this unit (Fig. 6), heat coils were replaced by delay-action fuses, but the line fuses were retained and a modified form of lightning protector was included. The lightning arrestors operated in the range 500–750 volts; the two line fuses were rated at 1·5 amp

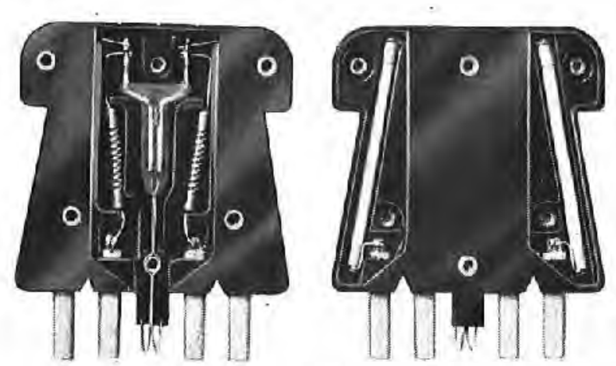


FIG. 6—WORKSOP TRIAL FUSE AND PROTECTOR PLUG

and ruptured in 30 sec with a current of 3 amp at 600 volts. The delay-action fuses operated in 210 sec with a current of 500 mA. The development of this frame did not, however, proceed any further, mainly because of the war.

Development of the Protector-Electrodes No. 1B

During the development of the Worksop M.D.F., attention continued to be directed to the possibility of modifying the protective arrangements at the exchange and at subscribers' premises. One of the components examined was the carbon lightning-protector since this, as outlined earlier, had a number of failings. This examination culminated in the production, in 1938, of a protector having two brass electrodes separated by a 2·3-mil spacer of cellulose acetate, the whole being enclosed in a plastic moulding. As originally designed, this unit had a break-down voltage of 400–600 volts. It was found, however, that it tended to break down when testing voltages were applied to the line and this feature, combined with a desire to relax manufacturing tolerances, resulted in some redesign, the electrode spacing being increased to 4 mils to give a breakdown voltage of 750 ± 150 volts. The redesigned unit was designated Protector-Electrodes No. 1B (Fig. 7).

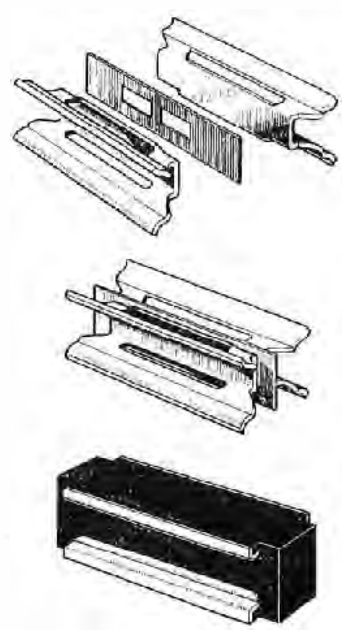


FIG. 7—PROTECTOR-ELECTRODES NO. 1B

Protection of Subscribers' Installations (1937)

In an endeavour to reduce the fault liability of the then standard protector unit for subscribers' installations (Protector, Heat Coil and Fuse, 2/2), consideration was given, in 1937, to the redesign of the unit. At that time, protection at the subscriber's premises was given by fuses rated at 1·5 amp (fusing current 3 amp), carbon protectors and heat coils. Each heat coil was mounted in spring clips and, if a current exceeding 500 mA passed through the coil, the heat generated was sufficient to soften the solder in 15–60 sec. A pin was then pulled out of the bobbin of the heat coil by the action of the spring clip and the circuit was interrupted.

The subscribers' unit, like its counterpart at the exchange, also introduced 10 contacts into the telephone circuit and this, coupled with the tendency of these contacts to corrode, gave rise to many faults. It was considered that if the number of contacts could be reduced by omitting the heat coil, the fault liability of the unit would be improved. It was also found that a number of faults were due to operation of the subscribers' fuses by lightning discharges.

It was ultimately decided that the heat coil could safely be dispensed with, and, to prevent frequent blowing of the fuses by lightning, their rating was increased to 2·5 amp. The lightning protector was, however, retained in the form of the Protector-Electrodes No. 1B.

In order to carry the above changes into effect, a new terminating unit for subscribers' lines was developed (Fig. 8) and this remains the standard unit at the present time.

FIG. 8—PROTECTOR UNIT FOR SUBSCRIBERS' INSTALLATIONS (PROTECTORS AND FUSES NO. 1, 2/2)

War-time Removal of Protection

In the 1940s a shortage of protector units prompted the Belfast Telephone Area to experiment with the omission of protection at the subscribers' ends of lines having only a short overhead component, four spans being fixed as an acceptable limit. No difficulties having been encountered where the technique was adopted, the circumstances were reported and an instruction was subsequently issued that protection could be omitted, with certain exceptions, from the subscribers' ends of lines having four or fewer overhead spans. Although this instruction was subsequently rescinded, the experience gained during its currency materially assisted in the formulation of the new protection policies described later.

In 1945, a further simplification was attempted when it was decided that it was not necessary to fit protection at the exchange and subscribers' ends of wholly underground lines. It was, however, difficult to segregate such lines on an M.D.F. from those which were not entirely underground, and thus all subscribers' lines have remained fully protected at the exchange. Protection at the subscribers' ends of wholly underground lines is now omitted as standard practice.

Elimination of the Heat Coil at the Exchange

In 1952 the question of protection was again considered and it was concluded that it would be desirable to eliminate the heat coil, provided that its protective function remained covered. This decision implied the availability of a reliable fuse to replace the heat coil. Development work on such a fuse had, in fact, already been carried out at the Post Office Research Station. In addition, a fuse having similar characteristics to the heat coil had been developed in connexion with the Worksop trial mentioned earlier. In this trial, however, it was augmented by a normal line fuse. What was really wanted was a fuse which, in effect, combined the functions of the line fuse and heat coil. The desirable characteristics of such a fuse were considered to be as follows, the corresponding figures for the line fuse being shown for comparison.

New Fuse	*Line Fuse*
Rated current 200 mA	Rated current 1·5 amp
To rupture within 5–300 sec when carrying 350 mA	To rupture with 3·3 amp within 30 sec
To rupture without fracture or arcing when connected in a circuit carrying 25 amp at 600 volts d.c.	To rupture without fracture at 25 amp, 600 volts d.c.

The heat coil, which the new fuse was intended to supersede, was designed to operate and earth the line in 210 seconds if more than 500 mA flowed in its winding. The most important innovation in the provisional specification for the new fuse was the lower current rating, which, it was suspected, might lead to the fuse being ruptured by normal line-current surges or in inconveniently large numbers during thunderstorms. This point could only be determined by trial in the field.

Fuse manufacturers did not find it difficult to make fuses to the foregoing specification, so a few hundred were made and a small-scale field trial arranged at Birchington exchange. A positive answer was not long in forthcoming from this trial, as the first severe thunderstorm in the area ruptured an unduly high proportion of the trial fuses. This settled the matter for the time being and made it evident that the desired fuse, apart from meeting the foregoing simple specification, must also be less prone to operation in thunderstorms—a fuse, in fact, which would stand a considerable overload for short periods of time.

A line fuse was eventually designed based on a type of fuse already in use in the inputs to power rectifiers. For this purpose delay is necessary to prevent the fuse being ruptured by the switching-on surge. The first fuses made were put on trial at Birchington exchange with encouraging results. Since then several thousands have been fitted in areas known to be subject to lightning storms and have given satisfactory service.

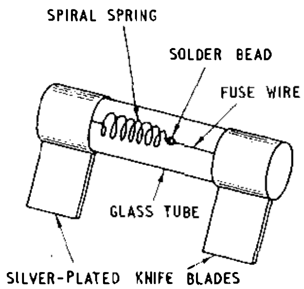


FIG. 9—DELAY-ACTION FUSE

The fuse element of the new fuse (Fig. 9), i.e. the essential operating portion as distinct from the carrier or housing, comprises three distinct parts: a helical spring, low-melting-point solder and fuse wire. Most of the electrical resistance of the element is in the fuse wire which, with sufficient current flowing through it, develops enough heat to melt the solder. On the melting of the solder the spring retracts and the fuse is open-circuited. With large currents the fuse wire will melt.

Although the fuse was originally developed as a 600-volt unit, experience in recent years has shown that the greater risk is now from 415/240-volt 50 c/s a.c. supplies. The new fuse (Fuse No. 64) is therefore rated at 250 volts.

PROTECTION STANDARDS ADOPTED FOR SUBSCRIBERS' INSTALLATIONS IN 1957

In 1957, attention was again directed to the possibility of simplifying the protective arrangements for subscribers' installations fed by lines having an overhead section. At that time, the protective arrangements were as shown in Fig. 10, and it was considered that, if

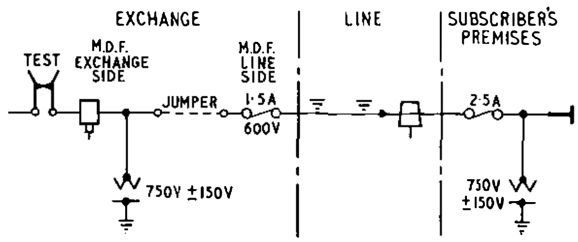


FIG. 10—PRE-1957 PROTECTIVE ARRANGEMENTS

these could be simplified, installation and maintenance costs would be reduced. In particular, it had been found that, with the arrangements then in use at the subscriber's end of a line, there was still a marked tendency for the fuse to be blown by lightning in spite of the increase in fuse rating introduced in 1937.

Examination of the problem showed that there were some grounds for the complete omission of protective devices at the subscribers' ends of lines having only short overhead sections. The only risks additional to those to which a completely underground line was exposed were direct lightning strokes and contact between the open wires and power conductors. Even if such contact should occur, the fuses then fitted at the subscriber's premises did not really safeguard plant at that end since the resistance of the power-fault-current path, i.e. power transformer, power line, point of contact, telephone line, subscriber's fuse, internal wiring, telephone-instrument earth and earthed neutral of the power system, was usually too high to permit sufficient current to flow to rupture the subscriber's fuse. The major cause of rupture of the fuse was in fact lightning surges through the fuse and lightning protector to earth, and it was this that caused much interruption to service.

The original intention was that the blowing of the fuse would prevent damage to the lightning protector, primarily when power contacts occurred. It also isolated the line from the subscriber's apparatus, which, theoretically at least, was safeguarded against damage. Whether, at least in recent years, the fuse really did what was required is open to doubt. There is, in fact, evidence to the contrary, since it has been observed that the explosive rupture of the fuses when lightning surges occurred often disintegrated protector units. Taking these circumstances into consideration, it was decided to dispense with fuses.

Normal telephone-line lightning protectors cannot be expected to provide protection against a direct lightning stroke to an overhead line but, so far as lines containing only short overhead components are concerned, there is evidence to show that the risk resulting from complete elimination of lightning protection is not great.

Examination of the policies of other administrations has shown that some only provide lightning protection if the line exceeds an appreciable length, e.g. $\frac{1}{2}$ mile.

These policies, coupled with the favourable experience in the United Kingdom during the 1940s, when subscribers' lines having four or fewer overhead spans were not fitted with protection of any kind at the subscriber's end, influenced the decision to modify the standard arrangements. The new standard, adopted in 1957, was as follows:

(*a*) Entirely underground circuits—no protection

(*b*) Lines with four or fewer overhead spans (including drop wire)—no protection

(*c*) Circuits with more than four overhead spans (including drop wire)—only lightning protectors to be fitted at the subscribers' premises.

The new standards were adopted immediately for new installations whilst existing installations were modified at subsequent maintenance visits.

REVIEW OF ARRANGEMENTS FOR PROTECTION OF EXCHANGE EQUIPMENT

The three protective components fitted for so many years on line terminations at the exchange take up a great deal of space, and economies could be realized if these components could be so modified that the physical dimensions of the M.D.F. could be reduced. Furthermore, the characteristics of the fuse, lightning protector and heat coil are such that they do not really safeguard present-day exchange plant satisfactorily. A critical review of the protective components was therefore undertaken, with the following results.

Heat Coils

About 500,000 heat coils are used every year and, although a large number are installed at new exchanges, many replace faulty items on existing M.D.F.s. It was, however, difficult to believe that the latter failures were all due to small leakage currents, particularly as it was known that the heat coil was prone to mechanical failure.

In an attempt to assess the proportion of mechanical to electrical failures, it was decided to conduct a controlled trial. Four exchanges, each having 1,000-2,000 lines, in areas where low-voltage (415/240-volt) overhead power distribution is extensively used, were selected for the purpose. The heat coils in these exchanges, 14,000 in all, were replaced by new ones and, for purposes of comparison and control, 200 idle heat coils were fitted in unwired protector units (Protectors, Heat Coil and Test, 40B) at each exchange.

The trials continued for two years and 48 coils failed. Forty of these failed mechanically, i.e. they showed no signs of electrical operation. One coil that failed in this way was fitted in an unwired protector unit. Of the remainder, three showed signs of electrical operation that could be related to known power contacts. The remaining five also showed signs of electrical operation, although no power contacts could be traced.

From this evidence there is some doubt whether the heat coil is a good investment, particularly as it has such a high fault liability and is known to be too insensitive to protect equipment adequately.

Complementary to the investigation into the performance of heat coils, information was collected of damage sustained by exchange and subscribers' equipment due to power voltages on Post Office circuits. During this investigation, which lasted for two years, 138 reports of power contacts were received. Of these, 115 recorded damage to exchange equipment; in some instances protective equipment operated, in others it did not.

There were also 34 power contacts which resulted in damage to subscribers' apparatus.

Fuses

One of the functions of the exchange line-fuse is to safeguard personnel and equipment against power voltages and currents appearing on external lines due to contact between those lines and power circuits. In the early days of telephony this risk was primarily from 600-volt d.c. tramway systems. The line fuse was therefore designed to be capable of interrupting the currents which, at that voltage, could be expected to flow when contact occurred between trolley wires and Post Office overhead conductors. Apart, however, from certain isolated systems, tramways are disappearing, and an assessment has shown that the risk is now mainly from 415/240-volt power distribution systems and that there is a case for reducing the voltage rating of the exchange line-fuse from 600 volts to, say, 250 volts. [illegible] action makes possible the reduction of the physical dimensions of the fuse, since one designed for 250 volts can be much shorter than one suitable for 600 volts.

Lightning Protectors

For many years it has been customary to fit lightning protectors on lines incoming to an exchange, and although such protection can be omitted from wholly underground lines, it is difficult to segregate such lines on an M.D.F. from those which contain an overhead component. In general, all subscribers' lines have been fitted with lightning protection on the M.D.F. This is a prodigal use of protectors, and economies could be achieved if they were fitted only where really required.

To help decide where such protectors should be fitted, it was arranged that all damage to subscribers' line plant and equipment due to lightning should be reported and the results analysed. During the period concerned 5,700 instances of lightning damage were reported. Some 5,200 have been analysed and the damage sub-divided into three broad classes:

(*a*) Subscribers' distribution points (D.P.s) and the cables to them (2,270 faults).

(*b*) Subscribers' equipment (2,730 faults).

(*c*) Power crossings (183 faults).

Of the 2,270 cases under (*a*), over 1,600 occurred in underground lead-sheathed cable, and Fig. 11 shows the distribution. A similar distribution occurred with aerial

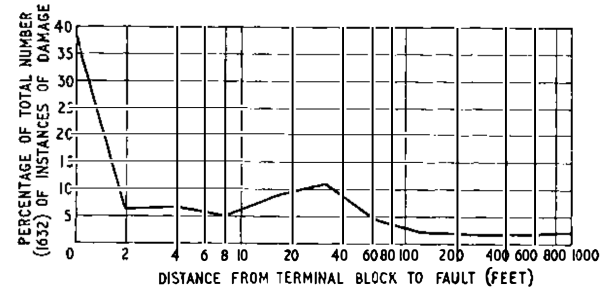


FIG. 11—OCCURRENCE OF LIGHTNING DAMAGE TO METALLIC-SHEATHED UNDERGROUND CABLES

metallic-sheathed cables, which were damaged approximately 400 times. There were also a few instances involving polythene aerial and underground cable.

Damage to D.P.s and their cables causes serious interruption to service and is relatively expensive to repair. It follows that a lightning protector is needed which will divert lightning surges to earth before they get into the cable network, implying that a lightning protector is required at the junction of overhead and underground plant.

NEW PROTECTION STANDARDS FOR EXCHANGES

From the considerations set out in the preceding paragraphs the conclusion was drawn that the old protective arrangements should be superseded by a technique employing, in addition to fuses at the exchange, a lightning protector at the junction of overhead and underground plant. There was, however, some doubt whether lightning protection was really necessary for all overhead lines, and it was decided that, to conform with the practice adopted for subscribers' installations, lightning protectors should only be fitted at the junction of overhead and underground plant when the former exceeded four spans.

As described earlier, considerable effort has been directed towards elimination of the heat coil, and this has resulted in the development of a fuse which should provide better protection than the old arrangements. This fuse was, therefore, incorporated in the revised protective arrangements, becoming the only protective item fitted at the exchange.

The revision of protective arrangements outlined above offered an appreciable saving in space at the exchange, and a new M.D.F. suitable for housing the new fuses has been developed.[2]

As the foregoing proposals would be far reaching in their results, it was decided to carry out field trials in

[2] Hix, K. W. The Telephone Exchange Main Distribution Frame. (In this issue of the *P.O.E.E.J.*)

areas known to be specially subject to lightning. In carrying out the trials, it was found that the number of subscribers' lines requiring lightning protection was only a small proportion of those connected to the exchange.

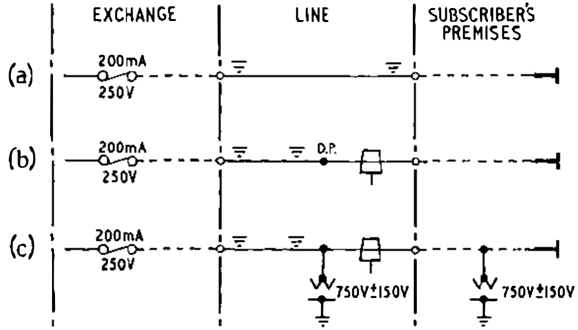
The type of lightning protector to be provided at the pole top was investigated but, at the time, no more suitable item than the standard Protector-Electrodes No. 1B could be found and it was therefore decided that these, mounted in a convenient unit, should be used. For D.P.s to which a number of long external lines are connected, a proprietary unit was provided in place of the standard terminal block. This type of unit will be used until a new item becomes available. If only a few pairs require protection, a protected terminal block is not economic and a unit has been developed for insertion in the head of an insulator.

These arrangements are not the only methods which have been evolved or are in use, but the results of the field trials indicated that the new protective arrangements could be introduced without undue risk. It was, therefore, decided that the new protection standard, so far as exchanges were concerned, should be:

(*a*) a fuse in every line at the exchange, and

(*b*) pole-mounted lightning arrestors on all subscribers' lines having more than four overhead spans.

Fig. 12 shows the new arrangements.



(*a*) Wholly underground line
(*b*) Line with four or fewer overhead spans
(*c*) Line with more than four overhead spans

FIG. 12—NEW PROTECTIVE ARRANGEMENTS

MAINTENANCE

If the new fuse is found to be as satisfactory in practice as on field trial, internal maintenance costs should be reduced. Improved protection of exchange equipment should also result.

Some concern has been expressed that the cost of maintaining external lightning protectors will more than offset the cost of repairing lightning damage to D.P.s and their associated cables. In view of the importance of this question further trials of the new protection arrangements are being conducted in the Plymouth and Peterborough Areas, where all exchanges in some maintenance-control areas will be changed over to the new system. Protective arrangements in the remaining maintenance-control areas will, however, remain unaltered and a record of maintenance costs will be kept for the modified and unmodified areas.

ACKNOWLEDGEMENTS

The changes which have been described are the culmination of the work of many past and present members of the Engineering Department over a considerable period. The author wishes to put on record his debt to those officers and to Regions and Areas for assistance in carrying out field trials.

The Telephone Exchange Main Distribution Frame

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The telephone exchange main distribution frame serves as an interconnecting point between the external street cables and the exchange equipment. The external cables terminate in cable-pair order on the line side of an ironwork frame, and the exchange equipment is connected in subscribers' numerical order on the exchange side. Fuses, heat coils and lightning arrestors have traditionally been mounted in units on this frame. A change in Post Office standards, which reduces the quantity of protective equipment to be provided for each circuit at the exchange, has enabled the frame to be redesigned so that more circuits can be terminated in a given space. Another objective of the new design has been the reduction of the fault liability of the protective and test interception components.

INTRODUCTION

FOR nearly 60 years it has been the practice to terminate subscribers' telephone lines on fuse mountings fitted on one side of an ironwork structure known as a main distribution frame (M.D.F.). The external cable pairs are terminated in numerical order on the fuse mountings on the line side of this frame and are jumpered (cross-connected) to other protective items mounted on the opposite (exchange) side. Although, from time to time, minor changes have been made to ironwork details and to the protective items provided, the frames now being installed do not differ materially from the first M.D.F. installed in the Carter Lane building for the London Central exchange in 1902.

The line fuse has existed in a number of forms, but since 1939 it has been the practice to provide fuses with a rated current of 1·5 amp in a Fuse Mounting No. 4028* on all subscribers' circuits, and the physical size of these items has limited the number of pairs which could be terminated on each unit of the frame to 220 (such units are usually termed "verticals").

On the exchange side of the frame, subscribers' circuits are connected in exchange numerical order to combined test and protective units. Although the testing, isolating and exchange-transfer facilities on this side are important, the units have the primary function of housing protective devices: heat coils to give protection against currents of insufficient magnitude to operate the line fuses but large enough to damage exchange apparatus, and protectors to safeguard the equipment from high voltages and lightning discharges.

Although it has been recognized for a long time that changes in the standard of protection were desirable and that protective components taking up less space would be advantageous, it has not been possible for various reasons to evolve an alternative standard until the present time. A design of M.D.F. based on the new standard of protection described elsewhere in this issue of the Journal‡ is now being introduced.

EARLY DEVELOPMENTS

Revision of protection standards was considered by a Post Office Headquarters committee in 1934 and it was subsequently agreed that there should be an experimental installation to try out new protective items. A novel delay-action fuse to replace the heat coil was designed and a frame incorporating new-type protective units was installed at Worksop exchange in 1938. This frame permitted slightly more circuits to be terminated in relation to its size than a conventional frame and there is no doubt that but for the outbreak of war the development would have been pursued. In the event, the development was shelved and after the war was further delayed whilst efforts were made to produce a delay-action fuse better suited to mass production than the item which had been used at Worksop. The developments leading to the introduction of the new type of fuse (Fuse No. 64), which will be used in future, are described elsewhere in this issue of the Journal.‡

SPRINGPARK EXPERIMENT

In parallel with the development of the new type of fuse, consideration had been given to alternative physical forms for the supporting framework, but no acceptable design had been evolved by the time it was decided that the fuse under trial was sufficiently promising to justify its provision in a complete exchange installation. It was accordingly decided that new fuse units should be developed to mount on the existing type of M.D.F. ironwork, and an exchange in the London Telecommunications Region (Springpark) was chosen to be the first exchange equipped to the new standard of protection. This exchange came into service in October 1959, and its M.D.F. has facilities for terminating 440 pairs per vertical on the line side and 300 pairs per vertical on the exchange side.

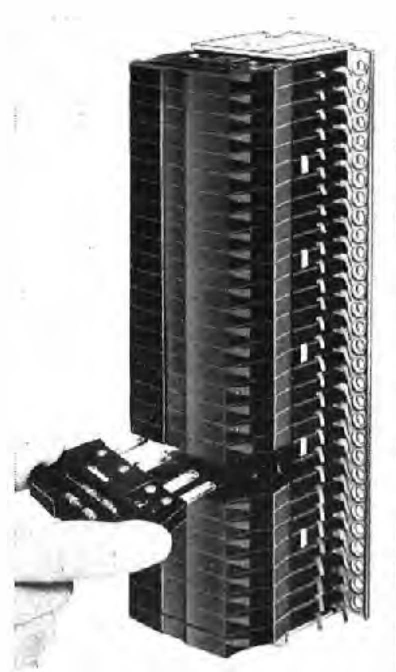


FIG. 1—FUSE UNIT USED AT SPRINGPARK EXCHANGE

† Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office.

* See Fig. 3 of "Protection of Exchange Equipment and Subscribers' Installations from Damage due to Lightning and Contacts with Power Lines." (In this issue of the *P.O.E.E.J.*, p. 220).

‡ LITTLE, S. J. Protection of Exchange Equipment and Subscribers' Installations from Damage due to Lightning and Contacts with Power Lines. (In this issue of the *P.O.E.E.J.*).

Fuse Unit

The fuse unit fitted on the exchange side of the frame is shown in Fig. 1. It is built up from 30 flat rectangular phenolic mouldings in which the contact springs are loosely laid. The springs are of "U" section at the front ends and are shaped to provide suitable tags for solderless connexion of the internal cabling to the intermediate distribution frame (I.D.F.) and to provide soldering tags for the jumper-wire connexions. The two fuses for an individual subscriber's circuit are mounted in a moulded carrier, and silver-plated contact springs project from the moulding. The unit can be adapted to mount on either side of the frame but, as a consequence of an earlier requirement to provide a design of carrier capable of accommodating fuses large enough to rupture safely at 600 volts, if the unit is used on the line side of the frame the terminating capacity of that side is restricted to 330 pairs per vertical. It was accordingly decided that at Springpark the units should be used on the exchange side of the frame, giving a capacity of 300 circuits per vertical, and that a terminating unit of greater capacity should be provided on the line side.

Line-Side Unit

A simple means of isolating each circuit and of giving access for testing purposes was provided on the line side by a link unit which had been developed by the Automatic Telephone and Electric Co., Ltd., for overseas use. The unit is physically interchangeable with the standard fuse mounting (Fuse Mounting No. 4028), has tin-plated tags for jumper wires on one side of the unit and external wiring terminations and space for silver-plated metallic isolating links on the opposite side.

Result of Experiment

Whilst the items used at Springpark have not been adopted as the future standard, the experiment was useful in demonstrating that the increased concentration of jumper wires that will occur on a more compact frame could in fact be accommodated, and the experience gained has materially assisted in the subsequent development work.

NEW DESIGN OF M.D.F.

The following considerations have largely determined the design of the new frame:

(*a*) A terminating capacity for at least 400 external cable pairs per vertical is desirable on the line side.

(*b*) The frame should be suitable for installation in existing buildings and in buildings planned to present standards as regards cable chambers and trenches.

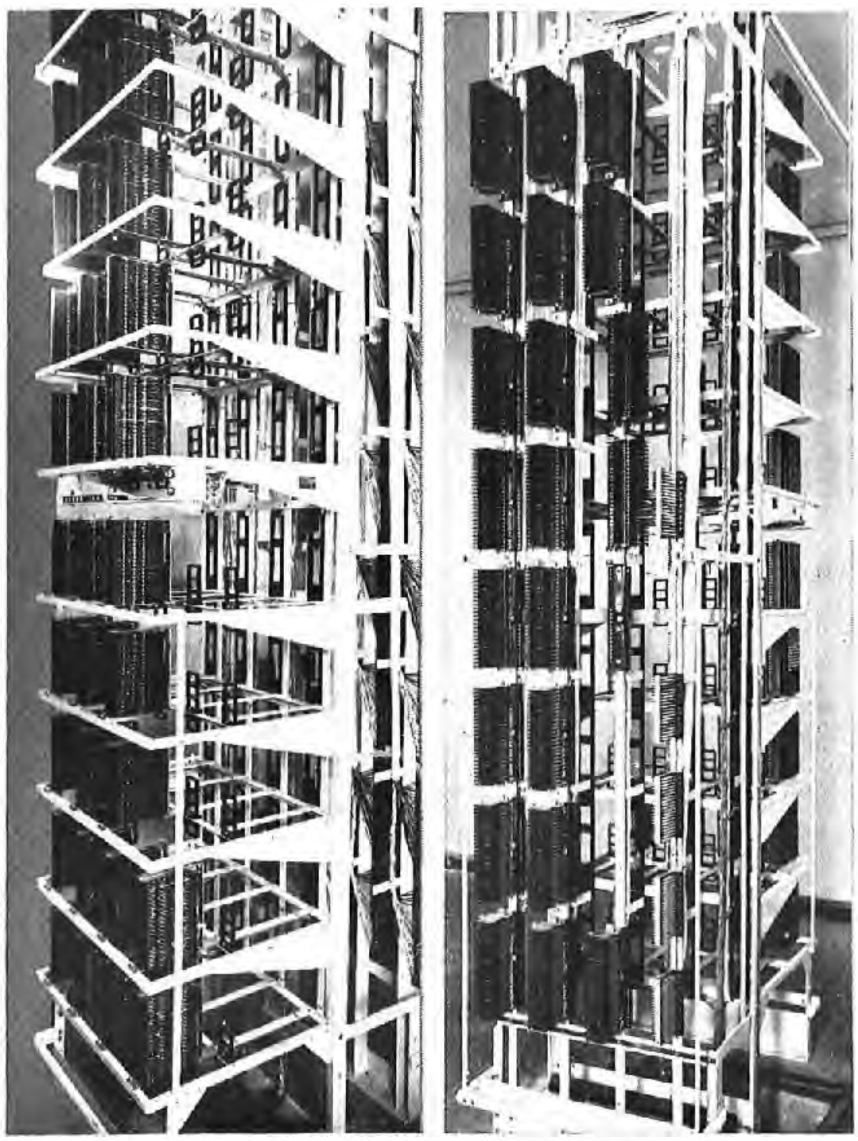
(*c*) Special footings should not be required, i.e. the ironwork should be suitable for floor fixing in a similar manner to standard exchange-type racks.

(*d*) The frame should be suitable for installation, in an apparatus room, parallel to suites of 10 ft 6½ in. high apparatus racks.

(*e*) Convenient test access should be provided on both sides of the frame and should enable exchange-transfer arrangements to be made in a simple manner.

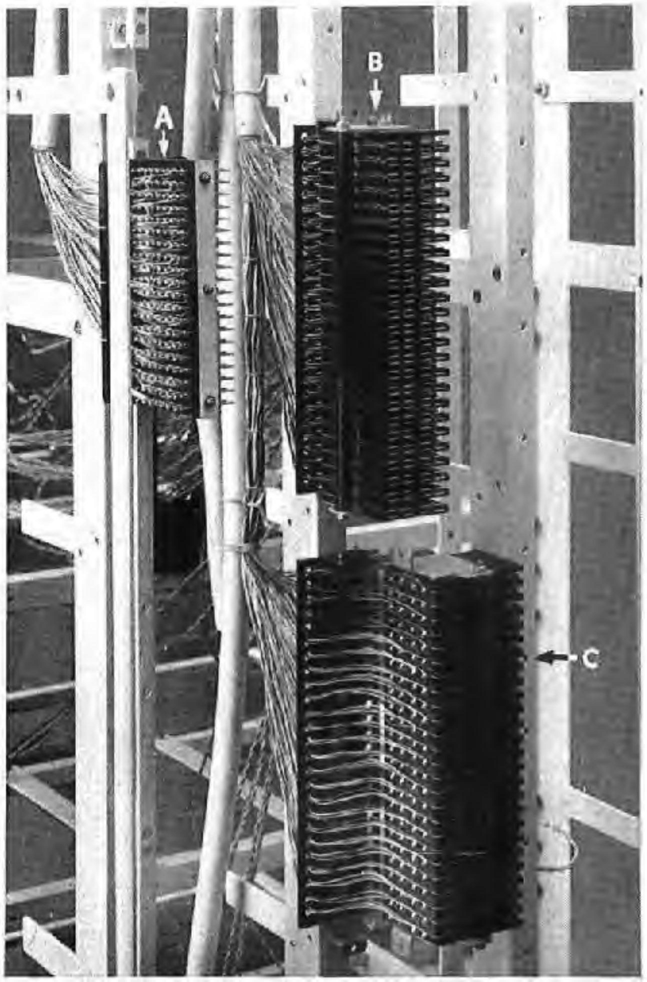
The new frame (Fig. 2), which is sometimes referred to as the Rack M.D.F., has a terminating capacity of 400 circuits per vertical on each side of the frame, the verticals being spaced 6¾ in. apart. Fuse units and connexion strips, together with jumper rings and the horizontal jumper field, are accommodated on the line side of the frame, whilst the exchange side is fitted with interception jacks and connexion strips. Connexion strips will normally be used for junction terminations on the exchange side and, as a result, 600 such circuits may be accommodated on each vertical equipped in this way.

Whereas a complete vertical on the old frame included



(*a*) Line Side (*b*) Exchange Side

FIG. 2—1,600-LINE UNIT FRAME



A—connexion strip; B—test-jack unit; C—test-jack unit swung outwards to facilitate access to permanent-wiring tags

FIG. 3—TEST JACKS AND CONNEXION STRIPS ON EXCHANGE SIDE

both line-side and exchange-side components, the new design has separate line-side and exchange-side ironwork units each consisting of four verticals. These units or racks are of standard height (10 ft $6\frac{1}{2}$ in.) but are only 2 ft 3 in. in length. A minimum terminating capacity for 1,600 circuits per rack is provided. The line-side rack is divided into ten horizontal jumpering shelves, and four fuse units are fitted on each shelf. The exchange-side rack is a simple structure provided with drillings suitable for mounting columns of interception jacks, connexion strips or both. Normally, eight 50-circuit test jacks (Jacks, Test, No. 33/1A) will be mounted on each vertical, but connexion strips may be used instead as desired, e.g. for junction-cable terminations (Fig. 3).

Although the line-side and exchange-side racks are separate, they are intended for installation back-to-back and, when braced together, form a stable structure. Line-side racks may be installed in advance of the exchange-side racks to facilitate cable terminating, but they will then need to be temporarily supported prior to the installation of the exchange-side racks. The racks will normally be mounted so that there is an overall distance of 3 ft 6 in. between the two guard rails. This distance has been dictated by the need to conform to standard apparatus-rack spacings so that the frame may be mounted parallel to apparatus racks if required.

Fuse Unit

The fuse unit adopted (Fig. 4) has a capacity for 80 fuses. The unit is relatively narrow (2 in.) and, since the mounting centres are $6\frac{3}{4}$ in. apart, hand access to both sides is reasonably provided for. The fuses are mounted on the left-hand side, as seen from the front, and the permanent-wiring and jumper-wire tags are situated on the opposite side. The 40-circuit unit is built up from 20 individual 2-circuit assemblies, which are interlocked by moulded dowels and clamped by two long bolts. Any individual assembly can be removed after slackening the nuts on the two bolts. Fanning holes for both permanent wiring and jumper wires are provided by extensions at the rear of the mouldings.

Individual assemblies comprise two flat plates with recesses for accommodating contact springs. The plates are riveted together and clamp the separate pairs of contact springs over approximately 1 in. of their length. The lower contact springs are of heavier gauge material than the upper flexible springs, and a combined pressure of the order of 300 grammes on the fuse blade is given. Independent twin-contact action occurs as the two springs are united at the wiring point on the opposite side as well as being clamped over their length. The springs are of nickel-silver and, with the use of silver-plated fuse blades, it is expected that reliable contacts will result. Nylon-filled black bakelite is used for the mouldings and an adequate margin of strength and insulation resistance is provided. Recesses are provided in the mouldings between the wiring tags to house the permanent wiring, which is thus protected from damage during jumpering operations.

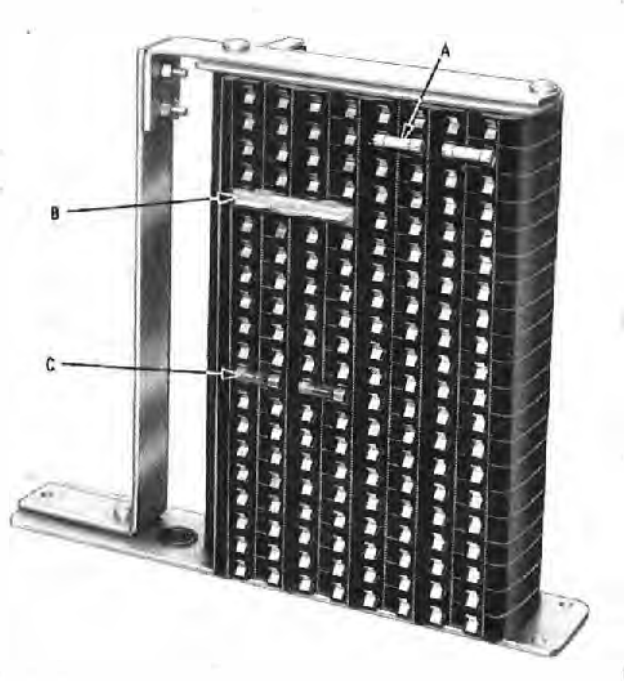
Exchange-Side Unit

Local distribution-cable pairs will normally be jumpered from the line side to interception jacks on the exchange side. The interception jacks have the simple function of giving access for test purposes to external plant and internal equipment. Interceptions at these points are usually infrequent, however, and circuits may remain uninterrupted for years. Reliable contacts are essential, and single silver contacts have been provided on nickel-silver springs tensioned to pressures high enough to ensure reliability. Test-plugs, which may be inserted into the front of the unit, engage with the nickel-silver surfaces and do not touch the silver contacts. The jumper-wire tags are provided on the right-hand side of the unit, but the permanent-wiring tags are at the rear of the unit. These tags have been designed with a view to their use for solderless connexions by means of wire wrapping and, as such, have sharp edges. The unit is mounted in such a way that it may be swung outwards so that it is possible to wire these tags from the side and yet have them away from possible contact with hands during jumpering operations.

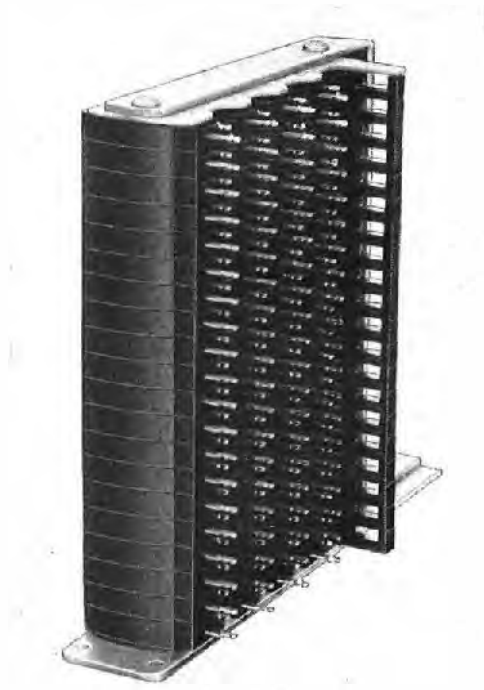
The assembly is built up of two-circuit units in a similar manner to that employed on the fuse mounting. A separate nylon-moulded fanning-strip can be fitted behind the unit on to a vertical mounting bar.

Jumpering

Although the M.D.F. is a useful testing point, its primary function is to provide flexibility between the external cables and internal equipment, and the success of any design is largely dependent upon the ease with which jumpering operations can be carried out. At first sight it would appear that, with an increased terminating



(a) Left-Hand Side showing Dummy Fuses (A), Fuse Covers (B), and Fuses (C)



(b) Right-Hand Side

FIG. 4—FUSE UNIT

capacity and reduced overall width, the concentration of jumper wires could result in some degree of congestion. Experience at Springpark exchange has shown however that, using the present standard $9\frac{1}{2}$ lb/mile jumper wire with its close insulation coverings, a terminating capacity of 440 circuits per vertical on the line side and 300 on the exchange side on the old-type framework causes no jumpering difficulty. On the exchange side of the new frame the jumpering space is virtually unchanged and, despite the increase in capacity, jumpering in this field should be quite satisfactory. On the side of the frame on which the jumper wires run horizontally the width of the jumper-wire bed has been considerably reduced. However, two important causes of congestion in the past have been the difficulty in recovering jumper wires no longer required and the obstruction caused by short jumper wires crossing at right angles to the normal flow. The new frame incorporates arrangements to enable jumper wires run directly between the back-to-back units to be routed in separate rings underneath the horizontal jumpering fields. It is hoped that the reduction in diameter of jumper wire and in overall frame length, with consequent simplification of recoveries, will further assist in ensuring that there is sufficient space for all horizontal jumper wires.

Jumper-wire rings of black nylon are being provided on the initial supplies of the new frame and if found satisfactory will be adopted as standard. The rings are supplied as part of the line-side unit and are provided in pairs immediately behind each fuse unit. A three-hole ring above the shelf enables three-level access to the horizontal jumper field to be given for jumper wires terminating some distance along the frame, whilst a smaller single-hole ring is provided immediately below the shelf to hold the jumper wires serving the units opposite. Two-hole nylon plates are fitted at the rear of the horizontal shelves with a small upper hole for the "within-unit" jumper wires and a larger lower hole for jumper wires entering from the horizontal field. A degree of resilience combined with strength and a low frictional resistance are obtained by the use of nylon for the rings.

Installation

Whilst the design and dimensions of the ironwork are such that the frame can be installed over a cable chamber and served by pipes through the floor in the conventional manner, a modification to the standard design of cable trench is necessary if it is desired to install the frame alongside such a trench. It is practicable with smaller installations to use a trench of reduced length and to feed the cables through a common hole or slot in the floor at the end of the frame and lay the cables underneath the horizontal jumper field. This arrangement, which will be used on the field-trial installation, will be of particular value should it be decided to terminate street cables directly upon the frame. With such an arrangement the facility of installing the line-side rack in advance will assist in forming out and terminating the cables. Protective dust-covers may be provided behind the guard rails partially to enclose such cables.

The external-cable pairs are distributed in blocks of 40 to each fuse mounting via the underside of the jumper field and a bushed hole in the base of the mounting plate. The fuse mounting has a single-hole fixing at the rear and can pivot about this point to give improved access to the permanent-wiring tags; these tags are appreciably shorter than the jumper-wire tags, and without the movement of the fuse mounting some wiring difficulty could be experienced.

Miscellaneous Facilities

As the standard fuse for subscribers' circuits has a rated current of 200 mA it cannot be employed safely on pairs used for such purposes as ringing and power leads. Circuits not exposed to any danger from power contacts or lightning, e.g. underground junctions, do not need any fuse. On all such circuits, dummy fuses will be used, and a design of fuse dummy has been produced consisting of a silver-plated metal link with an insulated body which gives to it the same size and shape as the standard fuse (see Fig. 4 (*a*)).

Covers have been provided to fit over the pair of fuses or dummy fuses for each circuit (see Fig. 4 (*a*)), and it is for this reason that the dummy fuse used is required to be of the same size as the fuse. These covers are made of red polystyrene and will be used on high-grade circuits to act as physical protection as well as markers to guard against inadvertent circuit interruption.

The fuses and fuse dummies are sufficiently small to present some difficulty to people with large fingers, particularly when it is desired to withdraw a fuse or dummy. Furthermore, there is always a possibility of the presence of a mains voltage when a fuse has ruptured and requires changing; it is intended therefore that fuses should not be withdrawn by hand but that a special tool should be used. A simple form of "sugar tongs" made from black nylon has been produced and it is expected that this will be cheap enough to permit a generous distribution for general use.

Special test-plugs have been introduced for obtaining access to circuits on both line and exchange sides of the frame. Advantage has been taken of the small size of the new fuse (Fuse No. 64) to introduce two of these items into the line test-plug, and thus protection of exchange equipment will be provided when a circuit is on test.

EXTENSIONS OF EXISTING M.D.F.S

The new fuse and interception units are unsuitable for mounting on the old standard M.D.F. ironwork and cannot therefore be used where it is desired to extend an existing frame. The new fuse mounting can, however, be adapted by the fitting of alternative mounting brackets of a form suitable for fitting on the line side of the existing type of frame to give a terminating capacity of 440 lines per vertical. The new 50-way interception unit cannot readily be adapted to mount on the exchange side of the present M.D.F., and accordingly a new 40-way interception unit, which is physically interchangeable with the present type of protector unit, has been introduced for use on the exchange side of existing frames. The springs on this unit are similar to those used on the protector unit, thus enabling the existing type of test-plugs to be used on the new units.

The new standard of protection cannot be introduced piecemeal into an exchange, and if it is desired, on an extension, to increase the capacity of an existing frame in the manner described above, it is first necessary to equip the longer overhead lines with pole-mounted protective units; when this has been done the heat coils and arrestors on the M.D.F. can be replaced by dummies, and fuses on the older type of fuse mountings changed to a delay-action type.

CONCLUSION

A field trial installation is proceeding at Cumnor exchange—a small non-director exchange in the Oxford Area—and the new frame will come into general use on new exchange installations in the early part of 1961.

The new M.D.F. is the result of development work by officers of several Branches and the manufacturers, and although the final design was carried out on behalf of the British Telephone Technical Development Committee by the Automatic Telephone and Electric Co., Ltd., the early development work of Associated Electrical Industries, Ltd., has been of value in bringing to fruition this change from an old-established standard.