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Time Recorders

THE statement "time is money" is supported by the fact that most of the recordings obtained from attendance or work-timing devices are used in connection with money payments or charges. It follows, therefore, that accuracy and reliability are essential in such devices, especially at the present time when owing to reduced working hours attempts are being made to increase the productivity per man-hour, which means, in effect, that minutes are tending to become of greater value in £.s.d.

It is now almost universal practice in industrial concerns of any size, to use automatic recorders for attendance or work timing, and whilst the machines described here may be used for either purpose they are primarily designed as attendance recorders.

In addition to accuracy and reliability, attendance recorders must be speedy in operation and also capable of withstanding rough usage. Apart from the convenience aspect, the choice of site is largely a matter of common sense, the most usual location being on the wall of a corridor near the cloakrooms.

Certain types of time recorders are arranged for manual "setting" but in the interests of accuracy it is desirable to eliminate the human element as far as possible, therefore, in modern design, setting is done automatically.

The Company is engaged in the production of two types of recorders ; one is fully automatic, i.e., the location and stamping is performed automatically when the card on which the recordings are made is inserted, and the other is automatic for the location of the recordings but the stamping is done manually after the card is inserted. For the purposes of illustration, views of the fully automatic recorder are shown.

In order to maintain consistent and accurate timekeeping over a complete installation, recorders are made to operate on minute impulses supplied by a master clock of suitable type, or by a synchronous motor working on frequency controlled a.c. mains.

Recordings are made on a ruled card, approximately 7″ x 4″ x ·011″/·009″ thick, on which each day of the week is represented by a separate vertical column. Consecutive recordings during the same day up to a maximum of eight, are printed one below the other, independent of the time interval.

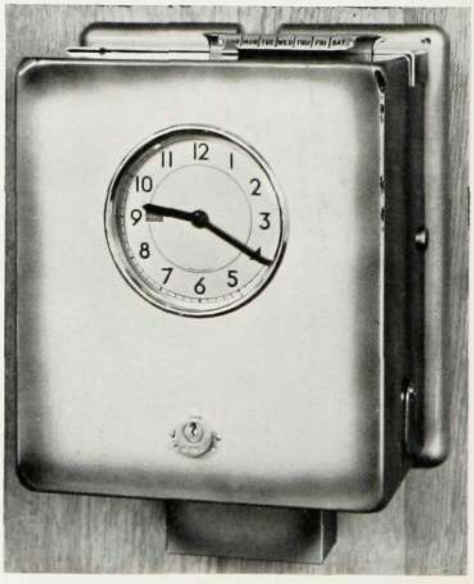


Fig. 1—A Fully-automatic Time Recorder.

The machine registers in hours and minutes and the standard marking is for 12 hours with p.m. hours underlined, but 24-hour marking and decimal divisions of the hour in place of the minute marking can be arranged.

Printing can be made in red or blue during different periods of the day, providing successive changes are not less than 12 minutes apart. For one day of the week the programme of colour changes can be made to deviate from the normal arrangements, if desired.

It will be seen from Fig. 1 that the unit is compact and has a neat appearance, and that the interior is well protected from dust or damage by a closely fitting enamelled steel cover which has a yale type lock.

External connections are made by means of a plug and socket in order to facilitate maintenance and inspection.

The internal apparatus is supported from thick mild steel sideplates (Figs. 2 and 3) held together by spacing bolts, and all bearing holes are bushed with manganese brass.

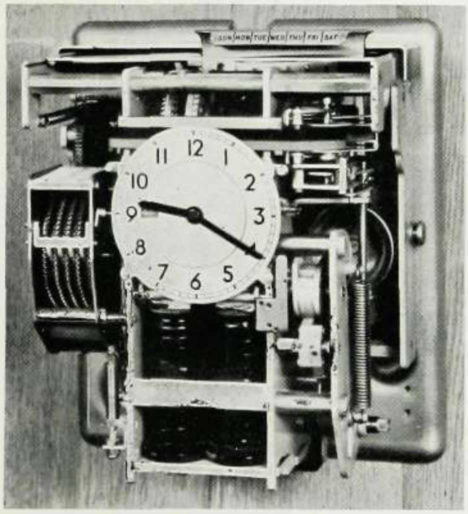


Fig. 2—Time Recorder with Cover Removed.

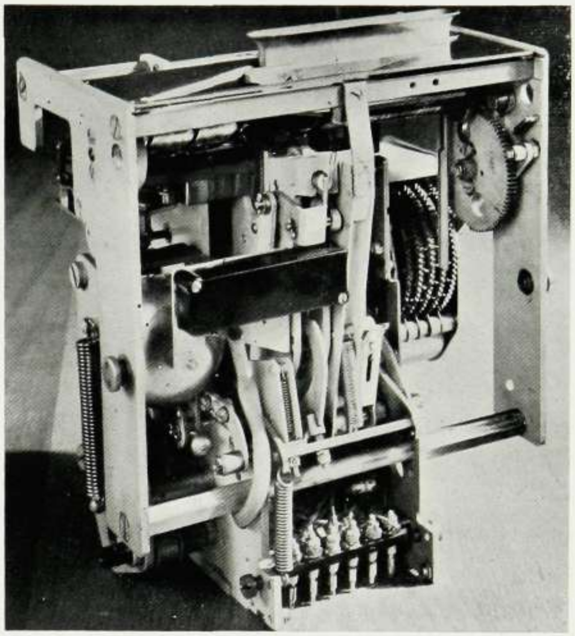


Fig. 3—Rear View of Recorder Assembly.

The mechanism comprises two sections, one being the time controlled units for indicating the time of day and for setting the characters and colour in preparation for stamping, and the other, the units for locating the card in the correct position and making the registration.

Time Controlled Mechanism.

The time controlled mechanism is driven from the main spindle (Fig. 4) on which is a 30-tooth ratchet wheel operated step-by-step at one-minute intervals by means of a pawl controlled by the armature of an electro-magnet. Pulses of 1-second duration sent out from the master clock, or its equivalent, are used to energize the twin coils of the magnet and the movement of the pawl takes place when the armature is released. A spring, brought forward to engage a gear-wheel on the spindle, prevents any movement of the latter whilst the armature is in the operated position.

Fitted behind a window in the front cover is a 4-inch clock face (Fig. 2), the hands for

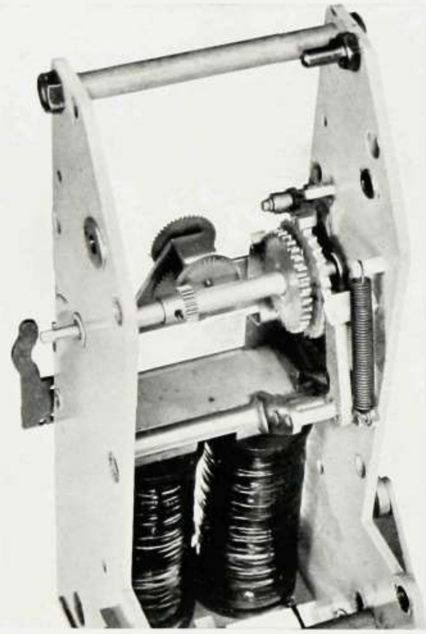


Fig. 4—Main Drive Spindle with Operating Pawl and Armature.

which are carried on an axle geared from the main spindle with a ratio of 1 : 2 for the minute hand and 1 : 12 for the hour hand, the latter being fixed to a sleeve over the axle.

Marking Wheels.

This assembly, shown in the top centre of Fig. 5, comprises two diecast wheels, embossed on the periphery for marking the hour and minute on the record card, two gearwheels and a trip disc.

The minute marking wheel, a 60-tooth gearwheel and the trip disc, are pinned securely to a spindle, the gearwheel engaging with another on the main driving spindle. The hour marking wheel and a 48-tooth gearwheel are keyed together and are free to revolve on the marking wheel spindle.

A spindle with pinion is fitted to engage the trip disc and the 48-tooth gearwheel so that for each revolution of the minute wheel the hour wheel is stepped forward 1/24 of a revolution.

Programme Unit.

To position the card holder for the appropriate day, control the colour of the printing and provide a means of operating an audible signal if required, a "programme unit" is employed. This unit may be seen on the left in Fig. 5 and includes four programme wheels, two being used for the respective a.m. and p.m. 12-hour periods over six consecutive days, and the remaining two for the a.m. and p.m. periods for the seventh day. A fifth wheel which carries a cam, is moved every time either of the p.m. wheels is operated, the cam working the day change mechanism which is released at midnight.

Each programme wheel is a diecasting having on its periphery 144 slots, spaced to represent intervals of five minutes. Hardened spring steel pins can be inserted in the slots to give any required time

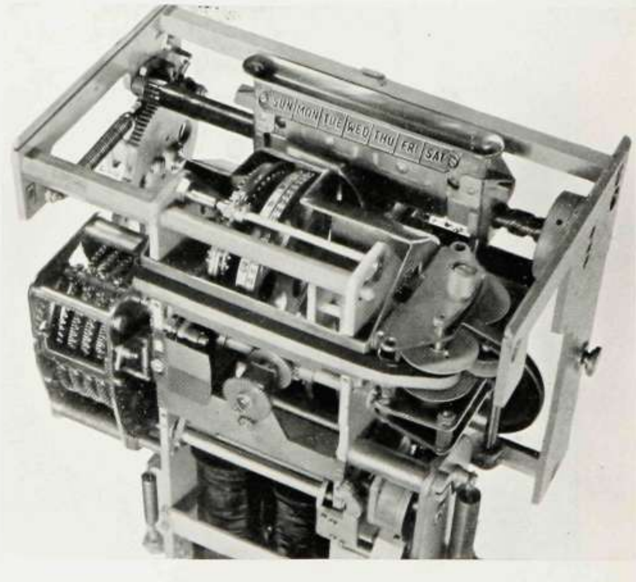


Fig. 5—Programme Unit (left) and Hour Trip Spindle and Marking Wheels (top centre).

interval, the pins being bent when necessary to register minutes within the five-minute spaces. The pins pass under the claws of a lever fitted across the face of the wheels and cause the slow rise and quick fall of a pendulum link on the side of the programme unit. This movement is utilized for colour setting.

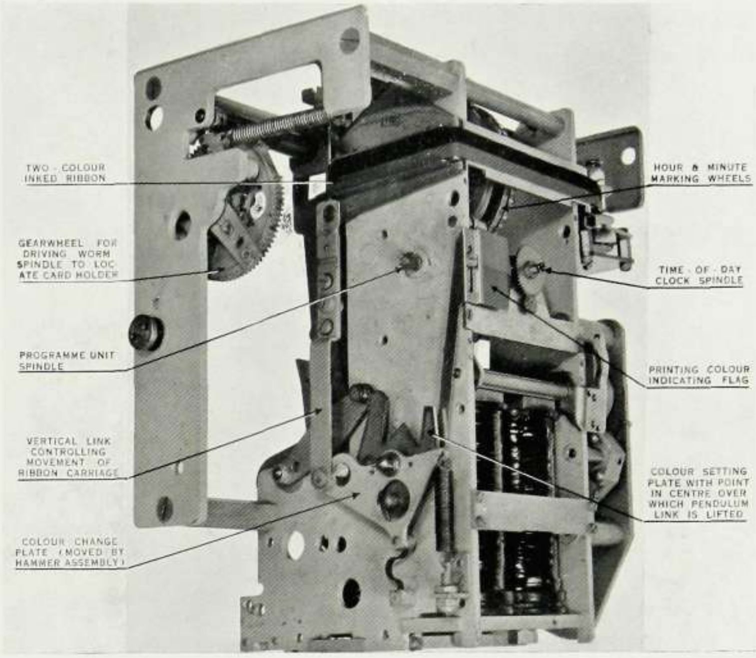


Fig. 6—Colour Setting and Colour Change Mechanism

COLOUR SETTING. (Fig. 6).

A two-colour inked ribbon is used for printing, and colour changing is brought about by moving up or down the frame carrying the ribbon, to bring the appropriate colour into position for the marking wheels. This movement of the frame takes place during the stamping operation but the colour setting mechanism functions at the specific pre-arranged time. The components used in the colour setting operation are the pendulum link mentioned above, and a setting plate which is fitted on a pin projecting from the recorder frame. A flag which is visible through an aperture in the clock dial (opposite 9) is attached to the setting plate and indicates the colour the machine is set to print.

The setting plate is shaped like a " W ", the centre point of which is free to move to a position on each side of the centre line of the link on the programme unit. As the link is lifted clear of the point of the W, by the action of the pins in the programme wheel, it swings and hangs vertically and when released, is made to fall on the side of the point opposite to that from which it was raised, thus turning the setting plate. With every rise and fall of the link the plate is turned in this manner.

CARD HOLDER AND CARD POSITIONING MECHANISM.

The card holder consists of a die cast mouthpiece riveted to a pressed steel frame which is screwed to a brass bracket carried on a worm spindle. (Fig. 5). The latter engages a thread in the carrier bracket to step the card holder from right to left corresponding to the day columns on the card.

The stepping movement is effected by a lever which is lifted by the programme unit during the p.m. hours and when the lever is released at midnight it causes a pawl to engage a ratchet wheel which drives the worm spindle by means of a gearwheel and pinion.

Teeth are removed from the gearwheel in positions corresponding with every seventh step, to allow the card holder to slip back to its starting position at the end of a week.

The gearwheel may be seen on the left in Figs. 5 and 6.

Recordings made on a card during the same day are positioned vertically one below the other as follows :—

A hole is punched in a card every time a recording is made (Fig. 7). A pointer, which is situated above the punch, is spring-tensioned against the face of the card and engages in the hole punched during the previous recording, to effect the correct location of the card for stamping.

REGISTRATION.

The printed record is made by means of an arm carrying a rubber pad which strikes the card and presses it against the inked ribbon under which the characters on the marking wheel are situated.

On fully automatic machines the striking arm is operated by an electro magnet which is energized by contacts fitted on the punch and vertical locating mechanism. These contacts are made when the card is correctly positioned and are automatically broken when the armature carrying the striking arm is fully operated. Interlocking levers make it impossible to operate the contacts again until the card is withdrawn and a new location made.

On the manually operated machines a pawl on the handle spindle engages a trip lever fixed to the striking arm. When the handle is depressed the striking arm is moved back against strong springs and is released suddenly at a set distance. In this way the weight and speed of printing is consistent under all conditions of the manual action.

The two-colour inked ribbon is carried round a diecast frame and is moved after each registration, being wound off one bobbin on to another. The action is automatically reversed just before the unwinding bobbin becomes empty and when the ink is exhausted the ribbon is easily replaced. A lever with roller, which is operated at the same time as the striking arm, moves the ribbon frame up or down according to the relative position of the colour setting plate.

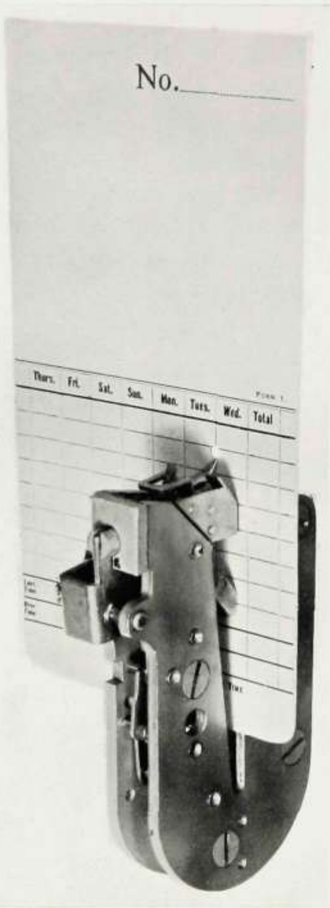


Fig. 7—Card Locating and Punching Unit

With the development of the fully automatic machine, numerous tests were made to obtain the maximum efficiency from the electrical operation of the stamping mechanism, in order to keep the time required for this function to a minimum.

A high-speed film, 2800/3000 frames per second, was made of the complete armature operation, which takes place in approximately 1/10 second, and the slow projection of this film proved to be of considerable assistance in the design of the movement.

An Attendance Aggregator

AS a result of the enquiry into the Bolton football ground disaster in 1946, it was recommended that, at all football grounds and similar places of entertainment, there should be equipment for indicating the number of persons passing into the enclosures, to enable admissions to be controlled. There are indications that the recommendation may become law in this country in the near future.

Some attempts have been made to safeguard the public against overcrowding as, for instance, by the erection of crush barriers and by the use of loud-speakers or megaphones for issuing instructions to the people in the enclosures ; furthermore the police exercise a certain amount of control by restricting further admissions to any enclosure which they deem to be filled to the safe limit.

Police action is in most cases based on visual assessment of the numbers present and naturally there is a tendency to "play safe", therefore it is quite reasonable to assume that money is lost by "sealing off" enclosures which may not be filled to the permissible capacity.

It will be evident that if some means of automatically and correctly registering information on the number of people in an enclosure at any moment is introduced, enabling restrictions on ingress to be imposed when necessary, the following benefits will result :—

(*a*) The safety of the crowd will be assured.

(*b*) The ground management will be relieved of much anxiety.

(*c*) Money will not be lost through over-estimates of the numbers in the enclosures.

(*d*) Officials and police specially appointed for controlling crowd distribution will not be needed.

Having long experience in remote counting and control equipment through the manufacture of totalisators and other calculating and registering machines, and with the components ready to hand in the form of automatic telephone apparatus, the Company was in an excellent position to develop a scheme for recording and aggregating individual turnstile operations for pre-determined groupings of turnstiles, and for providing a means of centralized control of turnstile admissions. A prototype aggregator was developed and built in the laboratory, where it was subjected to the customary thorough testing applied to all new projects, after which the system was installed for field trials and demonstration purposes at an actual football ground where the equipment was fitted to a group of 10 turnstiles controlling one enclosure, and

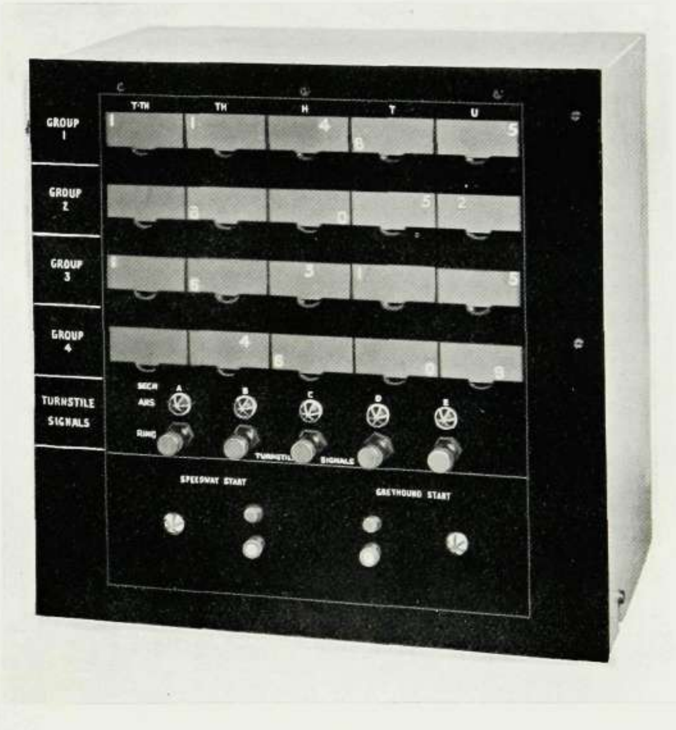


Fig. 1—Indicator with 5-Digit Displays for Four Groups of Turnstiles

was rigorously tested under working conditions. As a result the Company now has an aggregating and control system of guaranteed accuracy and reliability which can be installed at any place of entertainment where admission is controlled by turnstiles.

THE EQUIPMENT.

A robust mechanical contact enclosed in a weather-proof casing is bolted to the framework of each turnstile and is actuated once as each person passes through the barrier. The unit is so designed that it is impossible to record more than one entry per person, it can be fitted to any make of turnstile, and normally requires no maintenance.

The indicator, which is located at a central control point such as the manager's office, varies in size according to the number of enclosures or groups of turnstiles represented. The dimensions of the typical indicator with four group display units shown in Fig. 1, are $16\frac{3}{4}$ x $17\frac{1}{4}$ x 9 inches. Display units are composed of sets of telephone switchboard-type lamps arranged to illuminate selected figures in a perforated stencil plate, a principle which has been used on miniature indicators in the control rooms at greyhound race-tracks with great success.

The indicator illustrated is equipped for 5-digit displays which suffice for normal requirements although there are no restrictions in this respect, also the number of display groups can be varied to suit particular needs and if necessary the indicator can be duplicated in any remote part of the ground.

As the attendance aggregator is primarily designed to prevent overcrowding of each separate enclosure it does not normally register or display total attendance figures as these form no guide to the controlling officer on the density of the crowd in any particular section. If the total attendance figures are required, they can be obtained by simply adding together the totals for the various enclosures.

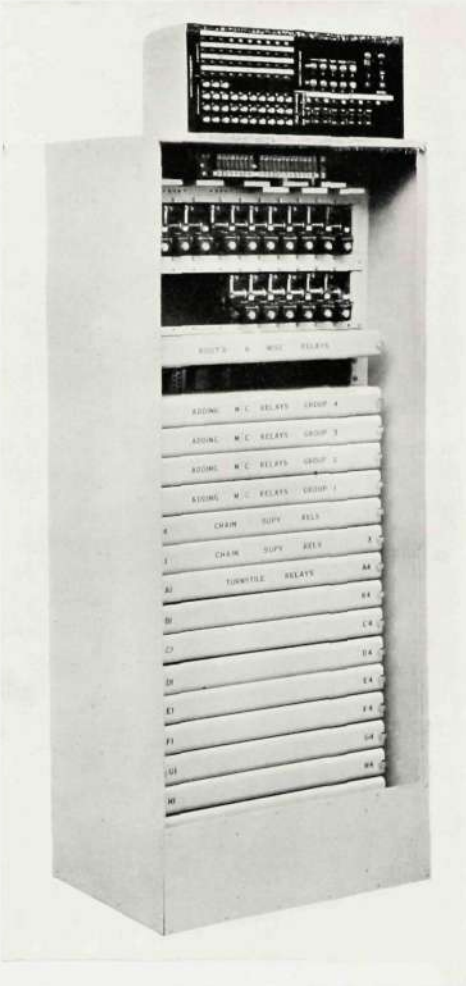


Fig. 2—Attendance Aggregator Main Equipment Rack

The lower portion of the indicator unit is fitted with equipment which enables the controlling officer to issue instructions to the turnstile groups and to receive notification that his orders have been put into effect. It will be seen, therefore, that this officer is fully cognisant, and in complete control, of crowd conditions without having to move from the room.

The totalling and controlling apparatus is mounted as shown in Fig. 2, which illustrates a rack suitable for grounds having a maximum of 50 turnstiles divided into 5 separate groups. If a greater capacity is required the rack is proportionately larger. The equipment, consisting mainly of relays and rotary switches, is protected from dust by removable covers and is readily accessible.

On top of the rack is a small panel accommodating supervisory and alarm lamps, equipment for controlling the automatic routine testing of the system and keys for isolating particular turnstiles for observation or testing purposes.

The system operates from the mains supply, through a rectifier if a.c., or a rotary converter if d.c.

At greyhound stadiums, etc., operating totalisators of the Company's manufacture, the same power plant can be used for the aggregator.

CONNECTIONS.

Telephone type multi-conductor cables are used for the main connections and 23 gauge double silk single cotton covered wire for local cables on the rack and indicator.

As there is a common earth lead per group for the turnstiles and only one wire from each turnstile to the equipment rack, the amount of cable required is not excessive, particularly if the rack is near the indicator and both occupy a central position.

OPERATIONAL PROCEDURE.

The controller brings the equipment into service by operating the master start key on the indicator.

The unit illustrated in Fig. 1 has two such keys owing to the fact that the stadium concerned is used for greyhound and speedway racing and the arrangement of enclosures differs for the two functions.

Admissions through each turnstile are summated automatically for each enclosure, the total being displayed in the appropriate unit of the indicator. When the maximum permissible figure for a particular enclosure is approached, the controller presses the associated turnstile group key which

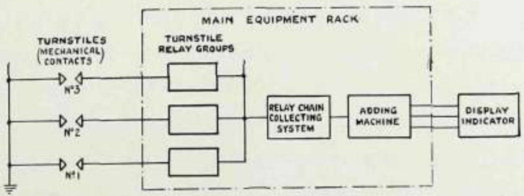


Fig. 3—Block Schematic of Aggregator Connections

operates a buzzer to notify the particular supervisor that turnstiles in his group are to be locked. After this has been done, the supervisor operates a key adjacent to the buzzer and causes a lamp fitted above the turnstile key on the indicator to glow, thus informing the controller that action has been taken.

The number of turnstile signalling equipments may not be the same as the number of enclosures, the former being arranged to suit the geographical location of the turnstiles. This is exemplified by Fig. 1.

As an alternative to the signalling system described, a small intercommunication telephone network can be installed, an obvious improvement on any scheme limited to signals.

As a precaution against failure of the system, facilities are incorporated for conducting a routine check of the equipment. This is entirely automatic and the apparatus is made to function exactly as in normal service over a brief period, or it can be regulated for testing at speeds well in excess of any practical demands.

CIRCUIT ELEMENTS.

A block schematic diagram of the system is shown in Fig. 3. Each quarter of a revolution of the turnstile closes the turnstile contacts, thus sending an earth pulse to the associated relay set where it is stored until the relay chain collecting system routes it into an adding machine. The circuit arrangements are such that an almost unlimited number of turnstiles can be associated with one adding machine and in the unlikely event of all turnstiles being operated simultaneously, all pulses are recorded without difficulty.

An indication of the efficiency of the system is obtained from the fact that the maximum delay period between the operation of the turnstile and the presentation of the altered total on the indicator is less than half a second.

The main advantages of the system are its accuracy and flexibility which make it adaptable to almost any situation requiring equipment of this nature.

The Physical Phenomena of Contact Operation

A very large number of contacts is used to establish and hold a telephone call. The failure of any one of these contacts would suffice to cause the call to miscarry, hence their correct functioning is essential to a smooth, trouble-free telephone service.

To connect a subscriber in, say, Birmingham with another in London will require several hundreds of contacts ; the number of operations performed in establishing the link amounts to thousands. Moreover, for the duration of the call twenty or more contacts are retained in use and imperfect continuity in any one would cause either interruption or background noise. This multiplicity of contacts has arisen from the development of automatic exchanges, and the comparative rarity of the miscarriage of a call in so complex a mechanism is really remarkable testimony to the reliability of relay and selector contacts.

This degree of perfection has been achieved by the progressive application of knowledge acquired from the early days of relatively simple installations. To a great extent this accumulated knowledge has been obtained empirically ; only in recent years has much attention been paid to the fundamental processes of contact operation, and the information at our disposal is still far from complete.

The perfect and enduring performance of contacts, as every electrical engineer is aware, has still to be achieved. Owing to the many millions of operations they are called upon to perform, their rate of wear and their effective maintenance are two important problems which are being studied in Britain, America, Sweden and Germany.

During the last two years the Company has been intensifying research into contact problems, and in this preliminary article will be discussed some of the theoretical aspects of contact operation that are generally recognized among specialists, but which may not be so familiar to many electrical engineers.

Ideally a contact should—

1. Make instantaneously at a prescribed moment.
2. Break instantaneously at another prescribed moment.
3. Offer zero resistance while closed.
4. Offer infinite resistance while open.

The ideal contact, however, does not exist, and practical success lies largely in the use of compromises whereby certain imperfections are tolerated in a known situation provided they are not detrimental to that particular use.

Let us now consider the physical factors affecting performance and the deviation from the above ideal.

Sparks and Arcs.

Sparks or Arcs occur whenever an inductive circuit is suddenly broken. They constitute a continuance or re-establishment of current after the contacts are open, and thereby violate requirement (4). They cause loss or transport of the contact material and would ultimately destroy the contact. Spark quench circuits must therefore be placed so as to divert the current from the contact gap and to reduce the current *gradually* without an excessive voltage surge. A spark quench circuit itself violates requirement (4) and must therefore in many cases be a compromise measure which does not entirely prevent a discharge, but reduces its duration.

Sparks and arcs possess certain similarities ; both have a negative impedance, $\frac{dE}{di}$; both require a minimum voltage ; for both, the voltage increases with the length of the air gap, and both cause evaporation of metal vapour from the contacts and produce characteristic spectral lines. The most noteworthy distinctions between them are the following :—

I. Sparks are momentary ;
Arcs can be maintained indefinitely (if sufficient current and voltage are supplied).

II. Sparks require 300 volts (minimum) in air ; Arcs require 15 volts (minimum) in air.

III. Sparks can form between cold contacts ; Arcs require a hot spot on the negative one.

IV. Sparks cause slight contact damage ; Arcs cause serious contact damage.

In the break of a contact an arc can form either from a hot spot formed on the contacts while touching, or from a hot spot caused by a spark ; frequently a high voltage surge breaks down the gap by a spark, which, being unstable, becomes converted into a low-voltage arc. The arc is eventually extinguished either by the increase of the air gap or the decrease of the voltage or current.

The current in sparks and arcs is carried partly as an electron stream from the negative contact and partly on positive ions drawn towards it. These ions are mainly positively charged atoms or molecules of nitrogen and oxygen when the contacts operate in air. The ionization energy of air molecules is about 15 electron-volts, hence a minimum of 15 volts must be available in order to produce them by electron impact. Electron bombardment of the surface of the positive contact detaches metal atoms from its surface. Because many of the detached atoms settle on the negative contact, metal migrates from the positive to the negative contact. This appears to be the usual action in telephone relay contacts in which arcing is nearly, but not entirely, suppressed. The accumulation of deposited atoms after millions of operations may be sufficient to necessitate the replacement of the relay. Maintenance is specially necessary in the case of tone relays, owing to the high frequency and continuity of operation.

AREA OF CONTACT.

The area of metallic continuity between contact surfaces is extremely small, depending on the contact force and surface contour. A *minimum* area is set by the hardness figure. The *actual* area is usually greater, but not much greater, than this minimum, because contact surfaces are never perfectly flat, both on account of tool marks and of wear during use. A typical example will illustrate :—

Example.

Brinell hardness : 100 (i.e. 100 kgm./sq. mm.).

Contact force : 100 gms. Minimum Contact area = ·001 sq. mm.

If the contact area were less than this minimum, the metal would yield until sufficient area was provided to bear the 100 gms. load without further yielding.

The area of contact at break is much smaller than the area of contact under pressure. Its calculation will be dealt with later.

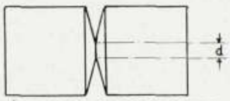
CONTACT RESISTANCE.

Two forms of contact resistance should be clearly distinguished :—

1. Resistance of the metal itself.

2. Resistance of an alien surface film of tarnish, grease or dust.

CONSTRICTION (OR SPREADING) RESISTANCE.



d = DIAMETER OF AREA OF CONTACT

These are terms commonly applied to the resistance of the metal itself. The constriction resistance arises in the immediate neighbourhood of the contact area, which, as we have already seen, is extremely small. The resistance of the rest of the contact is usually quite negligible, so that the length and diameter of the contact are immaterial. The only linear dimension involved in calculating the constriction resistance is the diameter d of the constriction (which, for convenience, we suppose to be one of circular cross-section).

The resistance of any conductor is calculated by dividing the specific resistance (resistivity) ρ of the metal by a quantity having the dimensions of length. The resistance R of the constriction is accordingly determined by dividing ρ by the only relevant length, d. There might be a numerical multiplier, but rigorous mathematical integration shows that the multiplier is 1. Thus the constriction resistance is :—

$$R = \frac{\rho}{d}$$

We have already seen that in a typical case the area of contact $\frac{1}{4}\pi d^2$ under 100 grammes contact pressure would be rather greater than ·001 sq. mm. ; a reasonable value for d would therefore be ·05 mm. For copper ρ is about ·000002 in ohm-centimetre units. With these figures the value obtained for the constriction resistance is

$$R = \cdot 0004 \text{ ohm.}$$

As an extension of this example the following table shows how the constriction resistance would vary with the diameter of the constriction :—

Variation of Constriction Resistance with Constriction Diameter

(ρ = ·000002 ohm-cm.)

Constriction Diameter d.			Constriction Resistance (ohms)
mms.	microns*	mils	
·05	50	2	·0004
·005	5	0·2	·004
·0005	0·5	·02	·04

*1 micron = 10^{-6} metre.

The extremely small size of contact areas at light pressures makes the "micron" a more convenient unit than the ordinary units.

SURFACE FILM RESISTANCE.

The tarnish film that quickly forms on polished copper consists of cuprous and cupric oxides formed by the progressive penetration of oxygen. These offer a high electrical resistance, and good contact between copper contacts is only obtained by breaking up the oxide film. On heavy switchgear, the forces are sufficient to do this, and copper, being cheap and easily worked, is an excellent material for many purposes, but its ready oxidation makes it quite unsuitable where the mechanical forces are light.

Silver does not oxidize, but forms a resistant black film of sulphide which can prove troublesome, especially in industrial atmospheres.

Chromium and aluminium form very thin, transparent, but tough, oxide films which preserve the lustre of the underlying metal from progressive oxidation, but owing to their high electrical resistance render these metals unsuitable for contacts.

There may also be a layer of attached oxygen atoms on the surface of gold, platinum, rhodium and other noble metals, but it is neither visible nor sufficiently thick to offer any resistance to the passage of a current. The contact resistance of noble metals with clean surfaces is entirely the constriction resistance within the pure metal itself.

Contact Temperature.

At the small area of contact the constriction resistance causes a voltage drop and therefore a dissipation of wattage in the form of heat. Between contacts closed under appreciable pressure the constriction resistance, voltage drop and heat generated are normally insignificant, but just before the contacts separate, the constriction becomes narrower as the surface becomes relieved of its strain, and the constriction resistance, voltage drop and wattage become, for an instant, appreciable ; the temperature of the surface therefore becomes high. There is, in fact, clear evidence that under average circuit conditions the metal reaches its boiling point as continuity is broken, and melts an instant earlier. This state of affairs exists only for a very short time—usually from about $\frac{1}{100,000}$ to $\frac{1}{10,000}$ of a second, and it is important to realize that the high temperatures extend only to an extremely small volume of material usually much less than a mil across.

Temperature—Voltage Relationship.

An analogy exists between the flow of current i under the influence of the potential gradient against the electrical resistance ρ, and the flow of heat Q under the influence of the temperature gradient against the thermal resistance $\frac{1}{K}$ (K denoting thermal conductivity). Hence

$$\frac{Q}{K} \div i\rho = \frac{\text{temperature gradient}}{\text{potential gradient}}$$

Since the heat Q is produced by the current i at a voltage drop V, we may replace Q by iV. Then

$$\frac{V}{K\rho} = \frac{\text{temperature gradient}}{\text{potential gradient}}$$

By integration we can deduce the following important relationship between the highest contact temperature rise T, and the voltage E, between a pair of contacts :—

$$T = \frac{E^2}{8K\rho}$$

Values for K and ρ can be obtained from engineers' tables, but as the values usually given are for ordinary temperatures some allowance must be made for the very high temperatures involved, and in practice it is necessary to increase the value for ρ about five times.

Voltages corresponding to melting and boiling temperatures of metals lie mainly between 0.5 volt and 2 volts. Indication of the voltage associated with both melting and boiling can easily be obtained on a cathode ray oscillograph of the voltage across a breaking contact, carrying an ampere or more, if only a few volts are used to supply the current.

The most important conclusion from the theory is that at voltages usual in telephone practice, the surface of breaking contacts must necessarily melt and reach the boiling point of the metal, even if no arc or spark is allowed to follow the break. The theory is certainly confirmed by experiments for currents of the order of an ampere, and accounts for the phenomenon of "bridging".

The voltage-temperature relationship does not involve the current i, so that melting and boiling takes place with either large or small currents ; but the quantity of metal affected is naturally greater in the case of heavy currents.

BRIDGING.

The phenomenon usually termed "bridging" is the consequence of the melting of a point on the contact surfaces just before separating. A "bridge" of molten metal hangs momentarily suspended between the separating surfaces and prolongs metallic continuity slightly later than would have been the case if the surfaces had remained unmelted. The volume of the bridge is only of the order of a billionth of a cubic inch in an average instance, its length and breadth being roughly proportional to the current. "Bridging" therefore becomes most pronounced with heavy currents. By carefully moving two contacts away from each other a very small distance while carrying current, it is possible to form a liquid bridge, to maintain it for some time, to observe its brilliant incandescence when formed between the more refractory contact metals, and to measure its resistance. With sufficient separation the bridge suddenly breaks, usually with a small explosion caused by the boiling of the metal. At the instant of the explosion the voltage between the contacts is the "boiling point voltage" of the metal. Afterwards, it rises to the battery voltage in a manner governed by the circuit characteristics.

Bridging is believed to be largely responsible (especially at heavy currents) for migration of metal from the positive contact to the negative one (or exceptionally in the reverse direction), with the ultimate destruction of the positive contact or locking of one contact into the other. The normal direction of bridge transfer is the same as the usual direction of arc transfer, and the consequences are similar, but the cause is believed to be fundamentally different and is receiving much study at the present time. Why metal from the positive contact should under almost all circumstances and with all materials be picked up by the negative one is not yet fully understood but is generally attributed to the Thomson effect—a property which an electric current is known to possess when flowing through a conductor in which there are steep temperature gradients. Electrons travelling from a hot part of a conductor to a colder part carry a certain amount of heat with them from the hot part to the cold part. Consequently the positive contact melts more than the negative one in forming the bridge, so that when the bridge breaks, some metal that came from the positive contact is left on the negative side of the point of rupture of the bridge. The cumulative effect of millions of repetitions of this process becomes easily visible.

Variants of this explanation are sometimes advanced and it should be mentioned that under some circumstances electrons appear to have the property of carrying "cold," not heat, along with them. This appears to occur in platinum contacts operating at low voltages.

Bridge transfer is not preventable by spark suppression circuits ; it is less marked in some materials than in others, but the only likely way of eliminating it seems to be the artificial heating of the negative contact or cooling of the positive one.

CONTACT MAKE AND BOUNCE.

To some extent contact make is the reverse process of bridging, melting being followed by freezing. Excessive currents arising from the discharge of spark quench condensers are usually prevented from forming serious welds by the inclusion of some resistance.

Contacts making at normal speed almost invariably bounce apart immediately afterwards and make again. This bounce (which may be repeated) often occurs so soon after make (sometimes after only a few millionths of a second) that it is not ordinarily noticed and may have no detrimental consequences other than an increase in wear of the contact surface. Bouncing is mainly a mechanical phenomenon that does not readily lend itself to mathematical treatment but is generally reduced to insignificant proportions by suitable design of contact mounting. Each new design is treated individually ; as the result of a large amount of acquired practice and experience the desired result is achieved after a few trials.

Modern Tooling Methods in Telephone Production

PRESENT world economy has created a demand for more, cheaper and better goods. To meet this demand increasing attention is being paid to production methods, and it is rarely that thorough investigation will not reveal possibilities of improvement in this respect by reductions in the numbers of manufacturing operations, elimination of wastage, the use of new materials, etc.

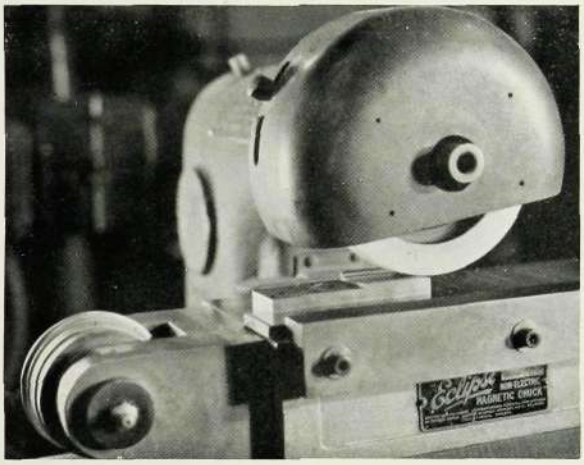


Fig. 1—Crush Form Grinding

The Company has achieved considerable success in recent years by carrying out such investigations, and two methods which have materially subscribed to this success are, the installation of additional machines of the most modern type, and improvements in tooling for the manufacture of component parts.

One of these improvements has been the introduction of a grinding technique known as crush grinding, a process which enables tools to be made to very fine tolerances and ensures that such tolerances are maintained on all replicas of the tools subsequently produced. An example of a crush grinding operation is illustrated in Fig. 1.

A crushing roller is made from alloy steel roughly turned to form and bored, heat treated, ground on the sides and bore, and finally profile-ground to finished dimensions on a form tool grinding machine, allowance being made according to differences in the depth and area of surface being crushed.

The crushing roller is checked on an optical projector against a master drawing ten times full size and is then mounted on a bracket fixed to the end of the magnetic chuck of a small surface grinding machine, on the arbor of which an abrasive wheel is fitted. The machine table is moved to bring the crushing roller under the grinding wheel which is slowly revolved as the roller is moved in under light pressure, to perform the crushing operation, a procedure requireing only a few minutes.

The hardened steel blank for the form tool is held on the magnetic chuck in the correct position relative to the profile on the crushed wheel. The power feed can now be brought into operation and the blanks ground to the required form, which is finally checked to a master drawing on the optical projector.

The efficiency that can be attained by this method is exemplified in the making of a small insert (made in batches of six dozen) for use in plastic moulding tools. Previously great difficulty was experienced by the tool service departments in meeting the demands of the production shops for this insert, the making of which involved much skilled work in filing and polishing operations. Manufacturers were unable to

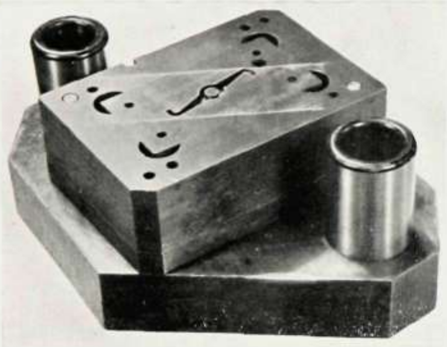


Fig. 2—Profile Ground Blanking Die

quote for the tool, being reluctant to guarantee the specified tolerances of ± ·0002″. The crush forming method adopted has resulted in a saving in time of 60% on toolmaking hours, 100% on production life, and an improved product. The cost of the special tools required to effect this saving was covered on the first lot of 72 inserts made. The high precision obtained is due to the close control that can be exercised in the various machining operations and the constant checking by optical methods against the master drawing, the scale of which is 25 times full size.

Profile grinding of blanking dies for press tools is a method adopted to obtain accuracy in piece part manufacture and longer die life. An untouched photograph of such a die, which is made in two parts, is shown in Fig. 2. The two pieces of alloy steel are roughly machined to shape, hardened as required and surface ground to size, after which each half of the die is form ground on an optical profile grinding machine, (Fig. 3), the toolmaker working by a pantograph arrangement from a profile drawing, fifty times full size, prepared by the tool design department at the same time as the tool drawings are made. After being ground, the die is sunk into a cast-iron bolster.

The requisite die clearance is allowed for in the setting up of the work on the machine and consequently the die will maintain size for much longer periods than is the case with hand or machine-filed dies which are hardened after the toolmaker has finished the shape and size to a template.

Careful and accurate gauging of manufactured parts are essential features in maintaining high class products, therefore the making and maintenance of gauges are important functions in the tool service departments. The introduction of modern thread grinding machines makes it possible to grind the thread on a hardened steel cylinder to produce a gauge, thus obviating the distortion that takes place when heat treatment is applied after the thread is die cut.

For cutting tools and gauges tungsten carbide is being used with advantage, but good results are also obtained on certain classes of press tools, particularly with carbide inserts on deep drawing dies, as exemplified by the increased numbers of parts produced by this type of tool in

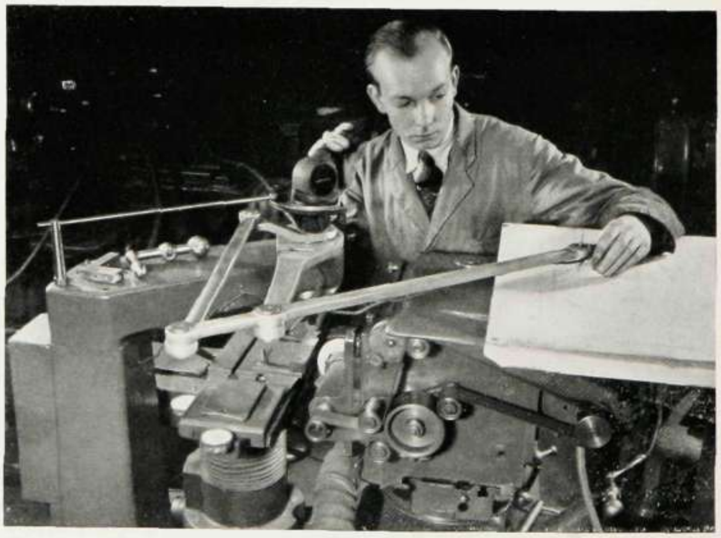


Fig. 3—Optical Profile Grinding Machine with Pantograph

making a rectangular brass case from sheet material, the average life of an alloy steel die being seven to eight thousand parts, against one hundred and sixty thousand parts produced from a die having a carbide insert. The initial cost of the latter is higher, but is fully justified by a life more then twenty times greater, also a better finish to the product, and freedom from production breakdown.

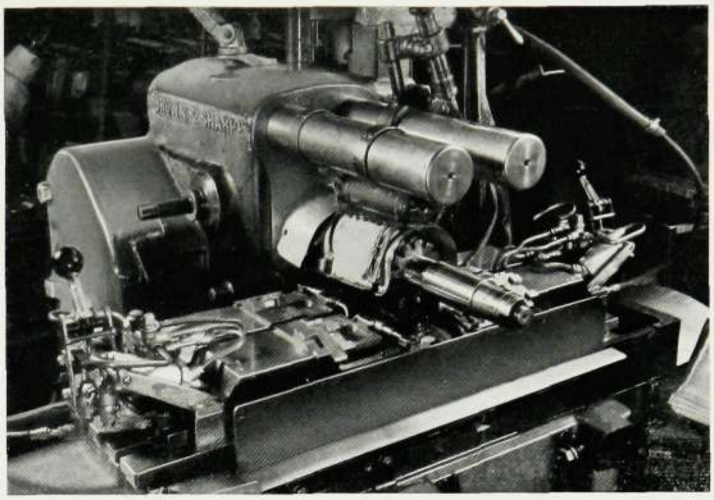


Fig. 4—Air Clamping Multiple Milling Fixture

Small reamers also are made from tungsten carbide round rod, the flutes being carefully ground in the rod after brazing into a steel shank. This particular application has proved very successful in the machine departments in spite of doubts at one time expressed, regarding the practicability of making very small tools from tungsten carbide. Another procedure which has proved of advantage is that of tipping drills with tungsten carbide ; a comparison made on a production run for a bakelite component, between the life of a tipped and the best type of untipped drill, revealing the remarkable proportion of 100 to 1 in favour of the former.

Grinding and lapping operations are very important in the making of carbide-tipped cutting tools, and much time was spent on experiment before the most suitable angles, clearances and the best abrasive to use, were decided upon. The most suitable spindle speeds are now specified on the designer's drawing, and to obtain efficiency and accuracy, care must be taken that machine bearings are maintained in first class condition.

Certain component parts which have to be made continuously in large quantities, warrant special purpose machine tools to speed up the various operations and keep the production lines moving. An example of this is concerned with the profile milling of "3000-type" relay yokes. Fig. 4 shows an electrically controlled milling machine with an air clamping multiple fixture, which, with form relieved cutters, was designed and made in the Beeston factory. This fixture accommodates four yokes, two on either side of the machine table, thus two pieces of work can be milled, and two loaded simultaneously.

The space between the loading and milling stations is traversed at high speed, and a single movement of the lever operating an air valve effects the location and clamping of the piece parts. The movement cycle is timed to allow the operator to load, unload and clean the swarf from the cutters and fixture.

Moulded plastic components are increasingly used nowadays and the design and preparation of moulds are branches of tooling which require specialized knowledge.

Success in forming moulded parts depends largely on the mould maker, whose skill can produce a die to very fine dimensions and with such a smooth finish that components can be ejected without distortion and require very little cleaning.

Aintree Telephone Exchange

WITH the opening of Aintree on the 22nd of January, 1949, the fifteenth automatic exchange in the Liverpool director area was put into service.

The original C.B. manual exchange was scheduled for replacement by an automatic system some ten years ago but owing to the war, the new building was not completed until 1947 and it was in September of that year that installation of the main equipment commenced, the M.D.F. having been erected five months before that date.

The area in which the exchange is situated is mainly residential but there are also factories of a number of light industries and further industrial development is anticipated. The famous racecourse where the Grand National is run, is close to the exchange and although the racing attracts very many thousands of people, the increase in telephone traffic at this time is of such short duration that it has been considered uneconomic to make permanent provision in the exchange to cater for it.

To give automatic service to subscribers on the orignal manual exchange, apparatus has been provided in the new one for 2400 ordinary, 800 P.B.X. 2/10, and 60 P.B.X.

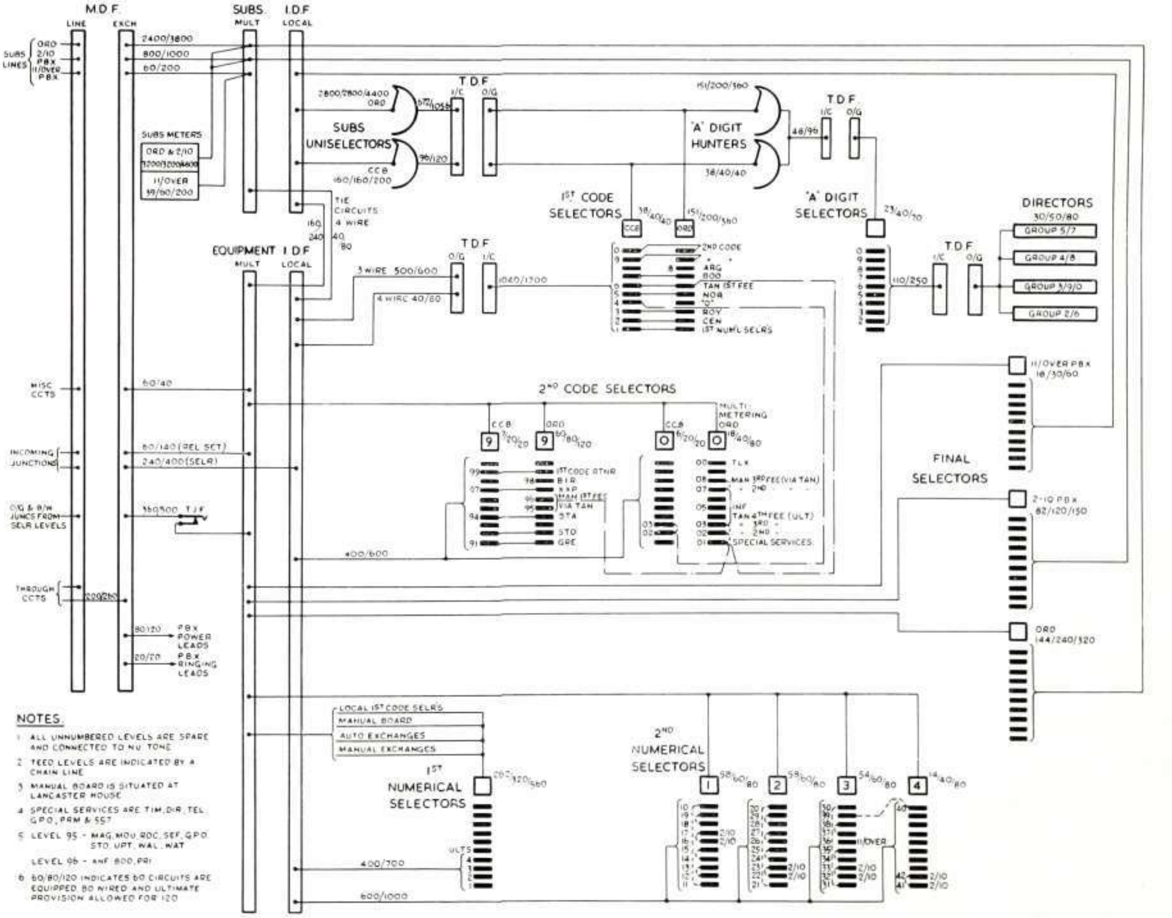


Fig. 1—Aintree Exchange Trunking

11/over, lines, and 660 junctions, but owing to the increasing demand for telephones in the area the installation of an extension comprising 1400 ordinary lines, 200 P.B.X. 2/10 lines and 240 junctions, started almost immediately after the initial cut-over and is now in progress. Pending the completion of the extension, the waiting subscribers are being given manual service by connecting them to the old Aintree exchange which has been retained for this purpose under the name of Argosy.

Trunking arrangements for the new exchange at the cut-over are as shown in Fig. 1 ; additions in respect of the extension are not included.

It will be seen that terminations are provided on the M.D.F. for 300 incoming junctions, 360 outgoing junctions and 200 "through" circuits, and that there are two intermediate distributing frames, one for subscriber circuits and the other for junction, miscellaneous and T.D.F. terminations, an arrangement which has been standardized for exchanges employing group selector racks having grading facilities. Four-wire tie circuits connect the two frames.

The fact that all group selector racks in this exchange are of the new grading type is a rather fortuitous circumstance in view of the pressing need for the extension of equipment and the consequent re-grouping and re-grading to be done. Each rack with its incoming and outgoing cables is a self-contained unit fully terminated on the equipment I.D.F., thus it is possible to vary existing switch groupings and gradings, as described in Bulletin No. 17, without disturbing cables previously installed, by re-arranging jumpers and bare wire straps on the racks and re-routing jumpers on the I.D.F. when necessary.

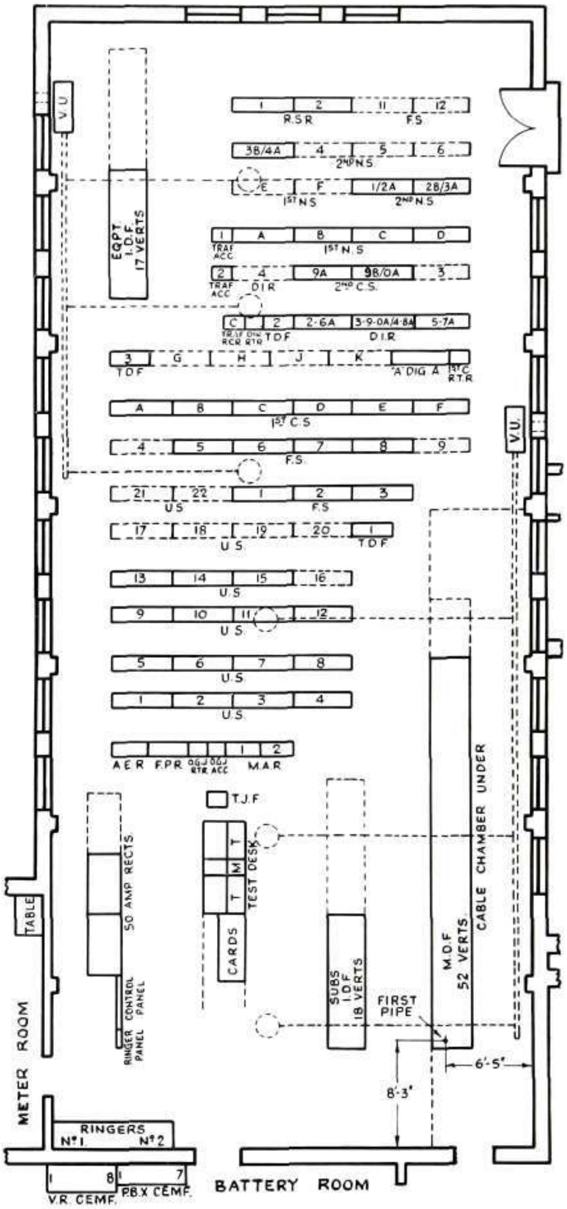


Fig. 2—Layout of Switchroom

Certain exchanges in the area are directly connected to levels of the code selectors, but access to the majority, including those in the 2, 3 and ultimately 4-unit fee areas, is obtained through tandem, which is located at Lancaster House with the central and joint trunk exchanges, all of which were manufactured by the Company and installed during the period 1939-43.

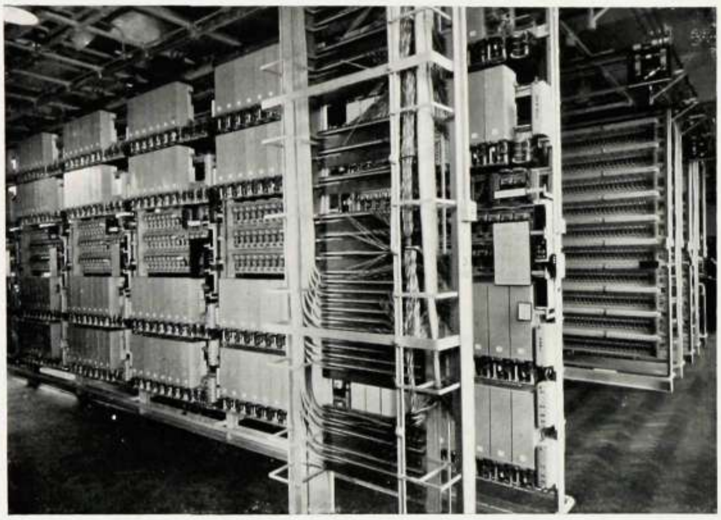


Fig. 3—Some of the Apparatus Racks, Aintree Exchange

The joint trunk exchange handles trunk and toll traffic for the whole Liverpool area, therefore calls to the manual board from Aintree subscribers are directed to the trunk exchange.

Fig. 2 shows a floor plan of the Aintree switch room in which is accommodated all the equipment excepting batteries and subscriber meters. External cables enter the building through a cable chamber from which they are led up to the M.D.F. through pipes in the floor.

The equipment racks are arranged in cabling sequence and it will be seen that the two I.D.F.s are at opposite ends of the room near the racks with which they are associated, therefore, with the exception of tie cables between the frames, cabling runs are relatively short.

Exchange testing equipment includes automatic routiners for outgoing junctions, first code selectors and directors, and a two-position test desk. Since the exchange came into operation, a scheme for the centralization of maintenance in the Liverpool area has been developed and Aintree has been selected as a control centre for several exchanges in the vicinity, with the result that two further test desk positions are being installed to provide the necessary facilities.

Part of the exchange equipment is shown in Fig. 3, first code selector racks being on the left, uniselectors on the extreme right, and in the centre a rear view of the T.D.F. associated with first code and "A" digit selectors. A power distribution fuse panel may also be seen attached to the overhead bus bars in the top right-hand corner.

Ringing current is supplied from a power driven machine of 1-ampere output and the usual arrangements are made for automatic change-over to a battery driven machine in the event of supply mains failure. The power plant operates on the parallel battery float system and consists of two 1100 a.h. batteries, two mercury arc rectifiers operating from a 400-volt, 50-cycle, 3-phase supply and having outputs of 50 amperes at 50 volts, a 150-ampere C.E.M.F. battery for automatic voltage regulation, and a C.E.M.F. battery for the P.B.X. 30-volt power supply.

Aintree is the first director exchange having all group selector racks of the grading type to be brought into service, but the chief interest lies in the opportunity for demonstrating the flexibility of the new cabling scheme during the installation of the extension equipment.

Monitoring Unit for Relayed Radio Programmes

RADIO has become of primary importance in this scientific age and some of the technical aspects of radio broadcasting are attracting the attention of a considerable proportion of the general public, therefore an outline of a recent development in the control of relaying equipment for broadcast programmes may be of general interest.

At the request of, and in collaboration with British Relay Wireless Limited, the Company has developed a sub-station control unit which incorporates facilities for manual monitoring, for the switching in of spare amplifier equipment and for closing down on all channels.

Illustrations of the unit are shown in Figs. 1 and 2, from which it will be seen that

Continuous efforts are being made by the radio relay companies to effect improvements in service to their subscribers, as represented, for instance, by recent increases in the number of programmes available, and by the provision of equipment which will help to eliminate disruption of service through circuit breakdown.

Radio programmes are relayed in this country over Post Office telephone lines to sub-stations, where, after passing through line terminating and equalizing equipment, they are fed into line amplifiers. One of two outputs from the latter is directed through a volume control resistance network, a main amplifier, and distribution switches to the subscribers, the other output being used to transmit the amplified programmes to other sub-stations in the network.

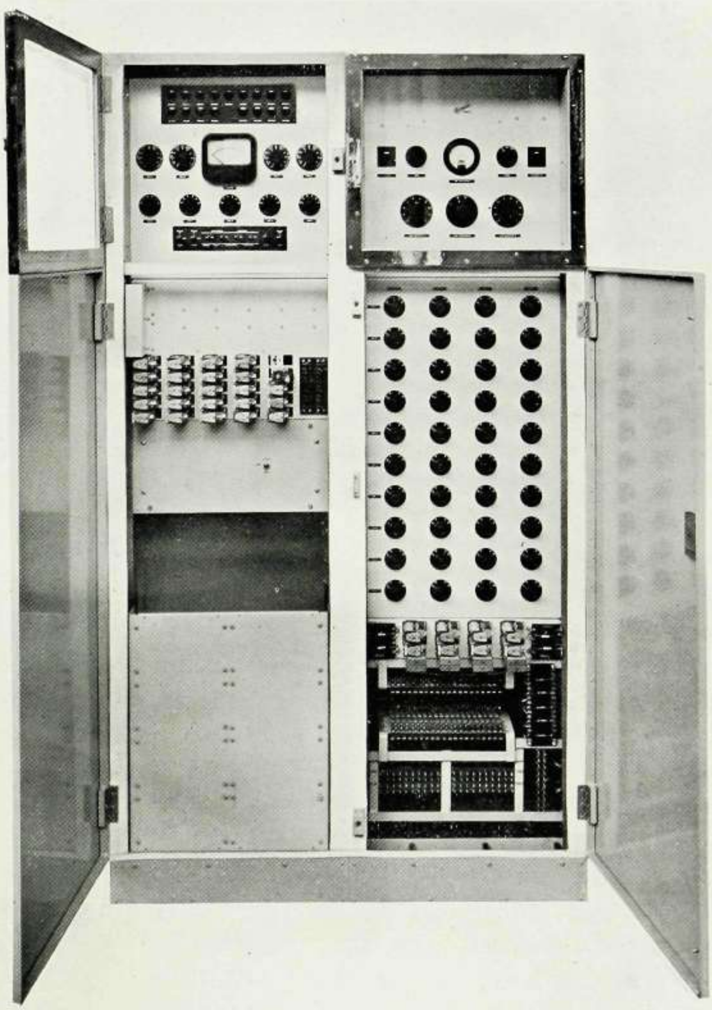


Fig. 1—Monitoring Unit—Front View

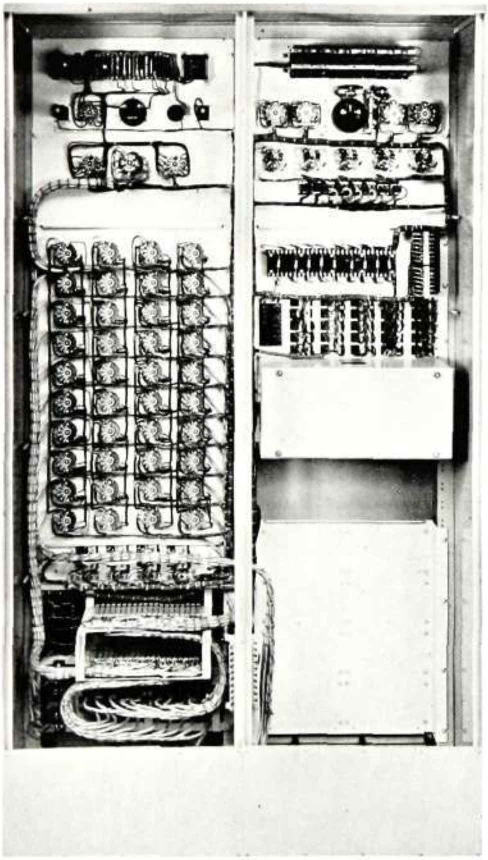


Fig. 2—Monitoring Unit—Rear View

the equipment is mounted in a metal cabinet having hinged doors in the front and removable covers at the rear providing complete protection and making the interior readily accessible. The upper doors have perspex windows to permit the observation of meters, indicators and switching controls.

The unit provides for the transmission of four programmes to ten groups of subscribers, the lines from which terminate on connection strips shown in Fig. 2 below the distribution panel accommodating forty programme control switches. Above this panel is mounted line testing equipment opposite which, in the left-hand bay, are placed the programme monitoring meter, supervisory indicators for revealing circuit conditions, volume control switches and lever keys for various purposes. Relays on this bay are used for signal control and for effecting the changeover from a faulty to a spare amplifier. Power is supplied from a 24-volt battery eliminator mounted at the rear.

Fig. 3 shows the amplifiers control circuit, which functions in the following manner :—

The programme signal from the line terminating and equalizing equipment enters the control unit through relay contacts S2 and S3 of the amplifier control circuit, from which it is directed out to the line amplifier where it is amplified and fed through a volume control element on the unit, to the main amplifier. The output of the latter is connected to the subscribers' lines via contacts MA1 and MA3.

A volume detecting relay in the main amplifier releases if the signal strength falls and remains below a pre-determined level for more than 3 minutes, or if the line condition is faulty, and causes an earth to be connected to the delay relays, thereby energizing the slow-operating relay AP which completes the circuit for relay AR at AP2 and AP3. Relay CH also operates through AP2, and its contacts connect a 50-cycle tone to the input of the line amplifier from whence the tone is passed to the main amplifier, where the amplified signal re-operates the volume detecting relay before A0 has time to function, and removes the earth from the alarm lead so that AP, AR and CH fall back. After approximately 3 minutes the volume detecting relay again releases and restores the circuits for AP, AR and CH. By this means, successive tone pulses cause periodic operations of the

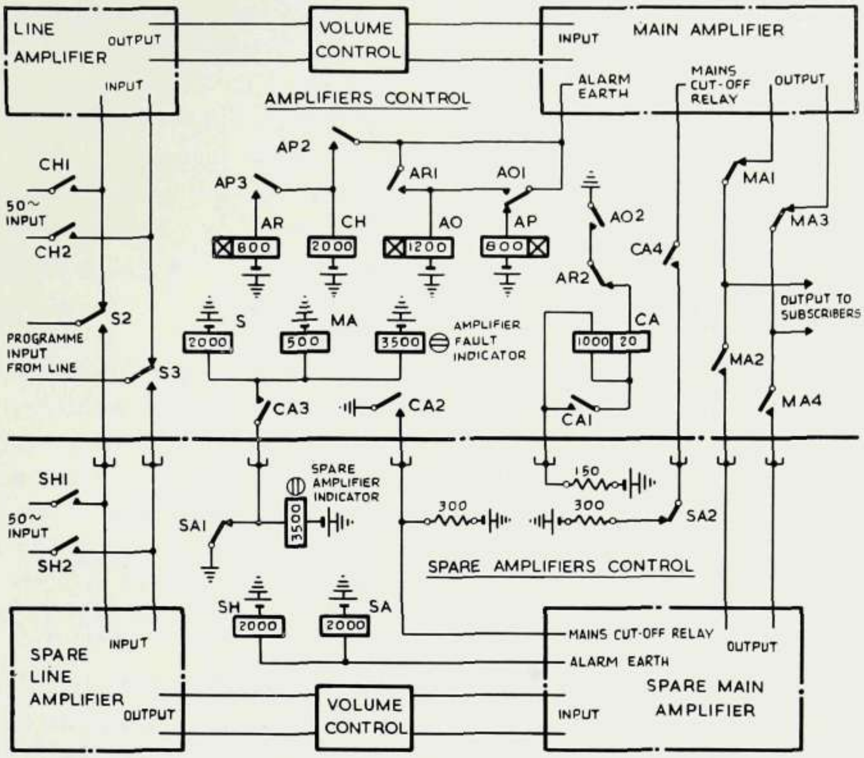


Fig. 3—Amplifiers Control Circuit

volume detecting relay until the programme is restored. The delay circuit is also made to function by the immediate connection of earth to relay AP if the extra high-tension or grid bias supply fails. Stand-by radio receivers are provided on some channels for supplying the programme when the line signal fails, and in these circumstances, as soon as a receiver commences feeding a signal into the line amplifier, the detecting relay will remain operated, with relays AP, AR and CH normal.

Should an amplifier become faulty, the detecting relay will not respond to the 50-cycle tone pulse after AR has operated, therefore A0 will slowly operate via AR1 and lock through its own contact.

With A0 operated, the circuits of AP, and consequently AR, are broken, and if a spare amplifier is available, a circuit is completed for relay CA. Contact CA1 short-circuiting the high resistance winding of CA, prevents the operation of any other CA relay, while earth on CA2 causes the mains cut-off relay for the spare amplifier to release through the shunting of the 300-ohm battery feed.

When the spare amplifier has warmed up, its volume detecting relay responds to the amplified 50-cycle tone pulse through SH1 and SH2 and removes earth from the alarm lead, thus releasing SA and SH.

The restoration of contact SA1 causes relays S and MA to operate and the programme signal is now fed through the spare amplifier via contacts MA3 and MA4 to the subscribers.

Manual monitoring of all parts of the circuit can be carried out by switch-connecting a level-measuring meter to

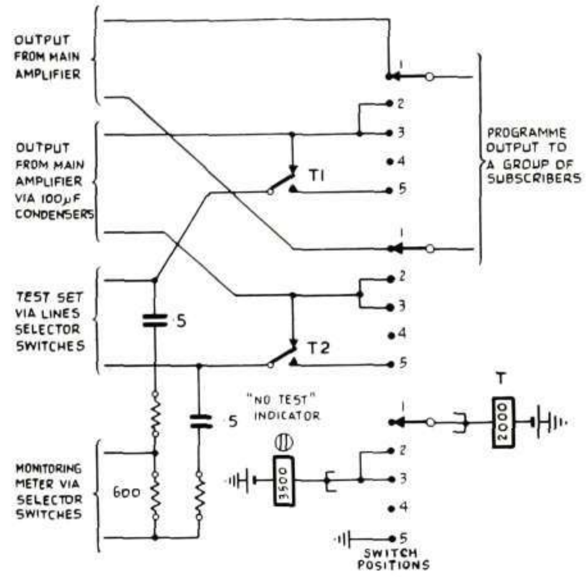


Fig. 4—Programme Distribution Switch Circuit

attenuators which are wired across the relevant inputs and outputs.

Typical circuit connections of a programme distribution switch are shown in Fig. 4, the normal route from the main amplifier to the subscribers being via switch position 1. Switch positions 2 and 3 feed the programme from the main amplifier via 100-microfarad condensers which enable the line insulation to be tested without interrupting the service. Position 4 is used to disconnect the group of subscribers when necessary, and position 5 for testing the lines with the programme cut off, the test set being connected by the operation of relay T. Relay T is commoned to all switches associated with the channel, and should another switch be set in position 2 or 3, a " no test " indicator operates to warn the attendant that the test element is connected to disconnected lines.

It will be seen that the monitoring meter can be connected either to the condensered output of the main amplifier or via switch position 5 to the subscribers' lines.

Auxiliary line amplifiers are used for relaying the incoming programme signals to other sub-stations and a relay is provided, and operated by a contact of relay S (Fig. 3), for switching in a spare auxiliary amplifier if necessary.

If desired, the programme channel associated with the spare amplifier can be disconnected and replaced by a different channel to enable another programme to be relayed. This is effected by a simple key operation which releases the CA relay in Fig. 2, thus allowing another CA relay to switch in to the spare amplifiers.

A feature known as the " close down " facility, has been incorporated in the control unit for the purpose of switching on or off the associated amplifiers in all sub-stations in the area, when a programme commences or ceases, thus avoiding the necessity for sub-station attendants having to be on duty after normal working hours. The amplifiers are switched off by a key operation at the control station, where battery, applied to the centre tap of the outgoing line transformer, operates a close-down relay at the sub-station. This energizes the mains cut-off relay, disconnects the main amplifier alarm earth and applies battery to the line, so operating the close-down relay at the next sub-station. The process is repeated through each sub-station in the control area.

To commence transmission, the close-down battery circuit is disconnected at the control unit, thus releasing in turn the respective close-down relays and causing the amplifiers to be switched on.