Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Wednesday, January 18th, 1956

The President (Mr. E. G. BRENTNALL, B.E.M.) in the chair

After the minutes of the Technical Meeting held on December 13th, 1955, had been read and confirmed, the **President** introduced Monsieur A. H. Morisset, Mr. J. D. Spoor, Mr. A. L. P. Smithies and Mr. W. R. Woods, who were present for the first time since their election to membership.

In calling upon Mr. H. Birchenhough to read his paper on " The Design of Signalling Apparatus," the **President** said that the subject was one of vital importance which had a great bearing on the successful operation of signalling and, therefore, on the reputation of the profession.

The Design of Signalling Apparatus

By H. BIRCHENHOUGH, M.B.E. (Member)

Diagrams—Inset Sheets Nos. 1-7

Signalling apparatus is revenue earning only whilst it is in service. Idle periods while apparatus is in storage, in the shops undergoing servicing, or out of action due to faults, are periods when the apparatus constitutes a capital investment which is unremunerative. Apparatus in depot stocks can be regarded as an insurance expenditure against the failure of apparatus in operation. The reliability of this apparatus will govern the quantities which must stand by for this purpose.

The main design requirements are therefore to create apparatus with the highest degree of reliability, which requires the minimum maintenance, and which will remain in operation for long periods before workshop servicing is necessary.

Full consideration must be given to servicing requirements, so that servicing costs and the time expended in the workshops during servicing are reduced to a minimum. A quick workshop " turn round " of apparatus enables lower stocks to be kept, and therefore fewer idle units, than a slow workshop " turn round."

Workshop servicing also necessitates stocks of components, the sum total of which will represent further idle units, so that attention must be given to reducing the range of component parts to a minimum.

Earlier papers read before the Institution have dealt with general design requirements, and the author has taken this opportunity to deal with the design aspect in more detail. The examples chosen as illustrations in this paper are, due to the author's service with the L.M.R., chosen from that Region's signalling material. It is hoped that this may lead to other writers more qualified to deal with types of apparatus used elsewhere contributing similar information to the Institution Proceedings which would be of mutual interest and benefit.

Signalling apparatus must primarily be able to function under the most adverse service and climatic conditions.

For adequate strength, construction need not be unduly rugged, as the weight of the apparatus itself can be a contributory factor in causing premature fracture.

The use of the malleable and special cast irons will increase resistance to fracture, and aluminium alloys such as aluminium-silicon will reduce weight as well as breakages.

Special attention should be given to the elimination of sharp changes of section on parts subject to shock loads such as levers in manual frames and weighted balance levers, etc.

Waterproofing

The presence of water in apparatus either by condensation or by direct entry must be prevented as far as possible by careful attention to gasketing of doors and inspection covers together with the sealing of wire and cable entry holes. The provision of glands or packings in bearings carrying drive shafts or operating rods through the external casing is essential on all outdoor apparatus to give protection against the direct entry of water.

The prevention of condensation is more difficult. Breathers suitably louvred and screened will reduce it to a minimum.

On outdoor apparatus the breathers must be located where they will not provide an entry for water.

Indoor apparatus does not require protection from water and the breathers merely require a fine mesh screen to prevent the entry of insects and dust.

The alternative to the use of breathers is a hermetical seal which is much more difficult to obtain and is restricted to apparatus opened only when undergoing servicing.

Such sealing should take place in cold dry air conditions otherwise sufficient moisture can be trapped within the apparatus to cause condensation once the dew point is reached, resulting in ice formation below freezing point, which could prevent the apparatus from functioning correctly.

Installation and Testing

Installation is expedited by the reduction of fixing bolts to a minimum and by providing simple mechanical connections with easy adjustment. Both installation and testing are assisted by placing electrical connections in the most accessible positions. The provision of well labelled terminal boards is recommended to ensure correct wiring and a wider use of multi-point plugs is suggested.

Maintenance and Inspection

For effective maintenance and ready inspection the following general provisions should be remembered :—

(*a*) Easy access to interior and exterior.

(*b*) Lubrication of working parts easy and reduced to minimum frequency.

(*c*) Surfaces easily cleaned.

(*d*) Ready adjustment and locking of mechanical and electrical moving parts.

For (*a*) Case doors and inspection covers should be simple to unfasten and secure. Elevated signals should be provided with adequate staging. Open doors should not foul the structure gauge.

For (*b*) Grease gun lubrication helps to ensure that lubrication is effective, and grease with high adhesion properties remains effective for long periods.

For (*c*) Smooth unbroken surfaces facilitate wiping down and cleaning, and inhibit corrosion.

For (*d*) Self locking screw adjustments help to expedite the setting of strokes, contacts, etc.

Production and Servicing

To reduce production and servicing costs the minimum number of components should be employed, and, wherever possible, sub-assemblies created which can be in production simultaneously, and which can be individually inspected and tested before being passed for complete assembly and final tests. If this is done test rejections of sub-assemblies will reduce delays in the production of the complete job compared with test rejections of the complete apparatus, due to a faulty component. To reduce the incidence of test rejections the designer should use the coarsest possible tolerances consistent with maintaining component interchangeability for all mechanical and electrical dimensions so that there is the minimum need for close control of production, and no necessity for selective assembly or hand fitting.

The use of thin shims of ·002-in. or ·003-in. thickness enables close working tolerances to be obtained on assembly without the necessity for close manufacturing limits. It is essential that all shims should be securely locked in position.

The use of the standard limits and fits specified in B.S. 1916, Part 1, 1953, is recommended, this Specification includes a wide range of limits from which those most suitable can be selected. Shaft and hole limits to H8-f8 are very satisfactory for mechanical signalling components where running fits are required. Apparatus should be provided with bushes or liners enabling renewal of wearing surfaces so that the same casting or forging can be returned repeatedly for servicing.

As apparatus returned to the shops for servicing is credited to the departmental account at a depreciated value, it follows that servicing costs must be less than the amount of depreciation to be economical.

General Design and Selection of Materials

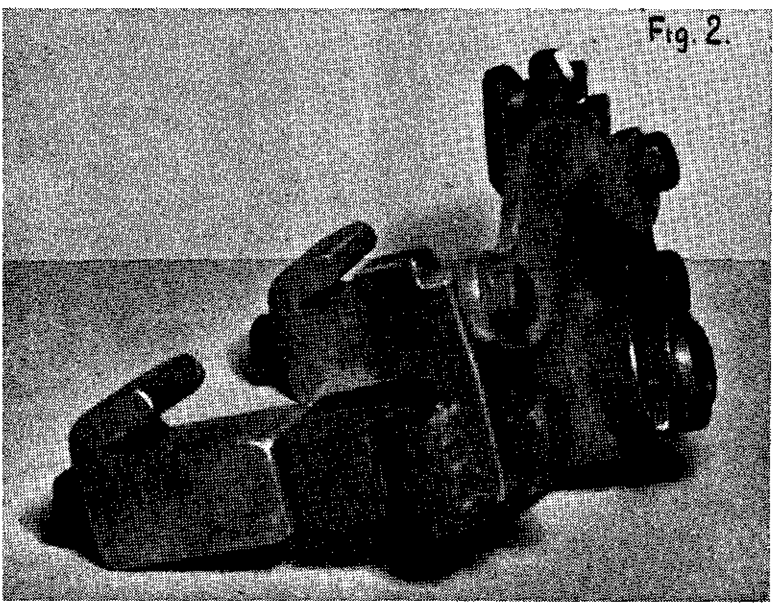
The appropriate B.S. Specification should be specified for any material used, e.g. cast iron to B.S. 1452, steel for forgings and bushes from the En. series in B.S. 970. Steel for pins and spindles and for rolled sections to B.S. 15.

Small cast iron components can be toughened by malleablisation but this process is unsuitable for the larger castings, for which pearlitic and nodular grey iron can be specified to give increased shock resistance.

Fabricated Steel Construction

Welding technique has advanced considerably in the past few years, and in the structural field enables the designer to save steel, and produce structures with cleaner outlines. For apparatus of all kinds it can be used in conjunction with flame cutting to produce complicated components hitherto only possible by drop stamping or forging. It can normally only compete economically with either of these processes on short production runs, but enables production to commence and continue whilst designs are being finalised, and dies prepared for forgings, etc. An example of this type of fabrication is shown in fig. 2, illustrating an F.P.L. bar rail clip for 109-lb. F.B. rail. This type of rail clip is fabricated by welding flame cut sections. By using this method, production is commenced quickly and maintained while considering production as a drop forging. It will be noted that the clip clamps on to the foot of the rail, so that drilling the rail for fixing bolts is eliminated.

The use of welding in steel casework and structural steelwork, is illustrated and described later.



Sintered Components

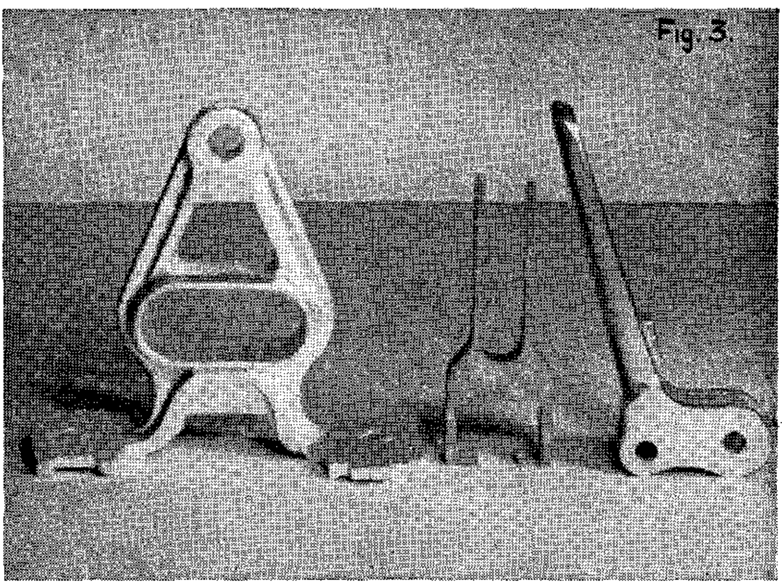
The sintering process enables fine limits and surface finishes to be obtained without machining. It offers advantages in the accurate production of small components and a lever frame employing sintered nickel steel locks with ult. tensile strength of 26-32 tons/sq. in. for the mechanical interlocking has been in use for some time with satisfactory results.

The die costs for this process are high and large quantity production is necessary to keep the price comparable with that of machined steel.

Alloys

Alloys such as aluminium-bronze, aluminium-silicon, zinc-aluminium, etc., lend themselves to small and medium size components, and by using die castings a high degree of finish can be obtained with a dimensional accuracy within ·001-in. per inch. The corrosion resistant properties of these alloys enable anti-corrosion finishes to be dispensed with, but care is necessary to avoid electrolytic corrosion between metals which are at different potentials to each other.

Particular examples are illustrated in figs. 3 and 4. Fig. 3 shows a die cast lever clasp handle and electric lever lock bolt in



aluminium-bronze, and a die cast point rod roller frame in aluminium-silicon alloy. Fig. 4 shows a die cast repeater contact box case, cover and crank arm in aluminium-silicon alloy. The die cast finish obtained reduces machining to a minimum, none being required on the clasp handle, lock bolt and point rod roller frame, and that on the contact box limited to drilling holes and facing the main bearing boss. The point rod roller frame is tougher and lighter than a cast iron frame which weighs 2-lb. while the alloy frame only weighs 11-oz. The high scrap value of aluminium alloy considerably offsets the initial cost of this material.

In the construction of electrical apparatus, plastics, high conductivity and hard wearing contact materials, and magnetic materials have all been improved in recent years.

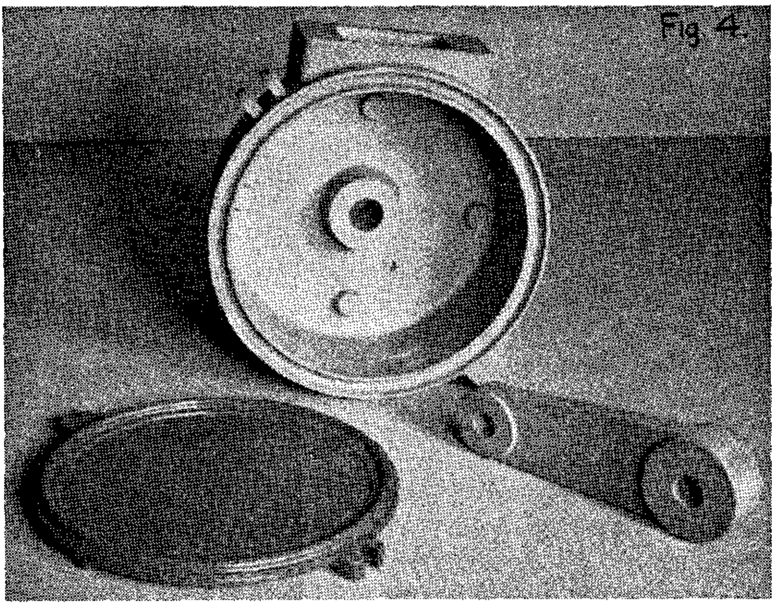


Fig. 4.

Plastics

The range of plastic materials now available enables the designer to select a plastic with the best mechanical or electrical properties for any particular application.

The thermosetting types are most suitable for instrument cases, terminal blocks, operating cams and other small mouldings. Of these the Phenolic resins are cheap and have good mechanical and dielectric properties, but are available only in dark colours. The Amino plastics, e.g., the Ureas provide a good colour range and are also cheap, but are prone to ageing shrinkage, which can set up undesirable stresses. The Alkyds are dimensionally stable and are available in a wide colour range but are higher in cost.

Moulding die costs are a major consideration, and are affected adversely by increase in size and complexity. Large quantity production is necessary to spread these costs thinly over the total output. When considering large casework in thermosetting resins costs can be reduced by adopting unit construction, thus reducing moulding size and increasing quantities required. The uniformity of the mouldings facilitates unit assembly of this nature, and can be used to advantage with such items as block instruments with each unit a complete self contained sub-assembly.

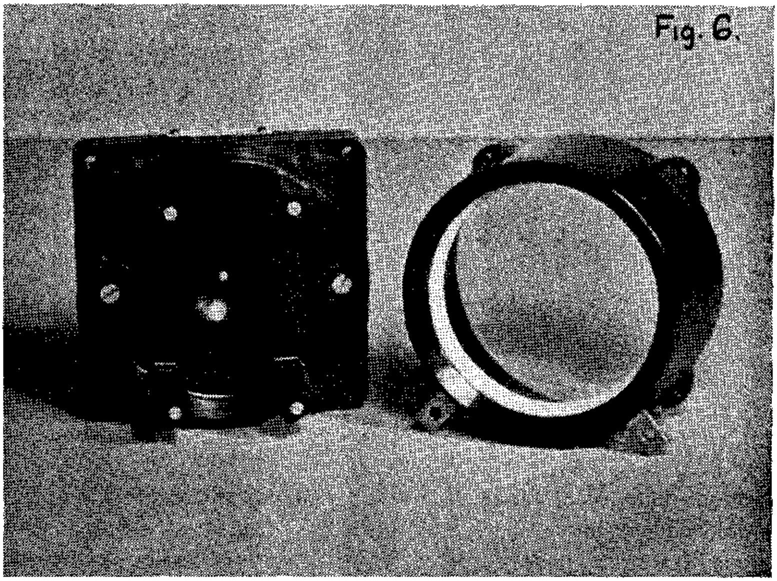
Of the thermoplastics, the Acrylic resins, e.g., Perspex, are useful for special lenses, the Cellulosics, e.g. Cellulose acetate, have been successfully used for cladding the lever handles of manual and power frames, being easily moulded to shape by heating or by softening in an alcohol solution. The Vinyls can be obtained with a wide range of properties, and the commonly used Polyvinyl Chloride (P.V.C.) possesses good insulating properties. This material has also proved very satisfactory as a cladding material for lever handles, being moulded to shape with a portable electric heater. The fluorocarbons possess high impact strength over a wide temperature range, and also have good insulating properties. Polytetrafluorethylene (P.T.F.E.) which possesses all these features is used for insulating bushes in the L.M.R. Pyrometer located in the hot gases rising from the semaphore signal oil lamp flame. This material is rather expensive and is only economic for small components.

The Nylons have excellent mechanical properties which makes them suitable for gears and bushes, it is necessary to stabilise these materials with a predetermined moisture content if dimensional accuracy is important.

Silicones and Butylenes in the form of synthetic rubber possess an immunity to sunlight, oils and greases which makes them suitable for all applications where natural rubber could not be used.

The above range of plastics is, of course, far from comprehensive, and other plastic materials such as the Polyesters, Caseins and Epoxy resins, etc., are also available with their own special properties.

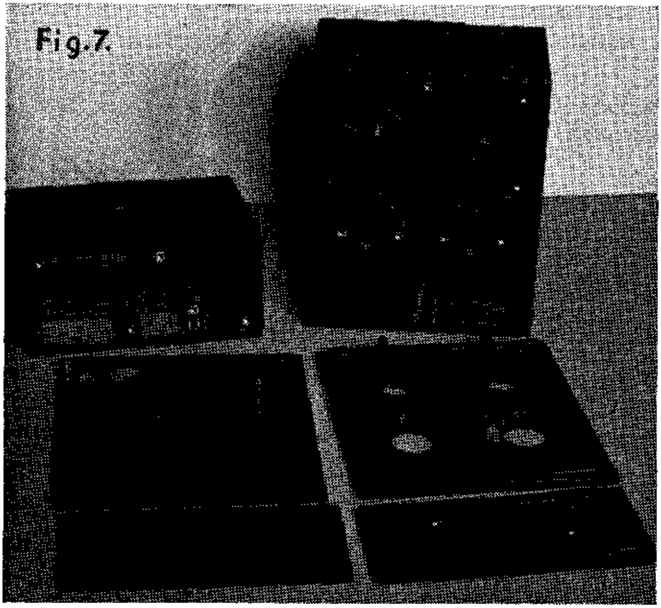
The illustrations, fig. 6, shows the moulded case for a signal arm repeater, fig. 7, the case for a signal light repeater moulded in Phenolic resin and fig. 8 moulded lamp units for theatre type route indicators which can be used for 110-v. or 12-v. lamps, in the same material.



Contact Materials

Silver Nickel alloys, silver to carbon and silver to silver are in common use. The selection of the particular type of contact is governed by the current to be carried and the permissible contact pressure. A wiping action is desirable to assist in the breakdown of any surface film which may form on the contact surfaces, and for this reason copper, brass and bronze are generally unsuitable for light duty contacts.

The method of attaching the contact material to the contact spring or carrier plate requires careful selection. Riveting weakens both the contact and the contact spring, contacts with shanks which pass through a hole in the spring and then riveted over are preferable. Brazing involves considerable heating which



may adversely affect both contact material and contact spring. Soldering is only suitable for light duty contacts. Electro deposition offers advantages in mechanical adhesion, electrical conductivity, and increased hardness of the contact material, but has limitations in contact thickness, silver can, however, be deposited to a maximum thickness of ·05-in. Contact bimetal is also available with a facing of contact metal bonded to a suitable backing material.

Contact Springs

Beryllium-copper has superior properties for use as contact springs having a high electrical conductivity combined with high mechanical properties. Contacts can be silver brazed on to the material before final heat treatment. Phosphor-bronze provides a good alternative although slightly inferior to beryllium-copper. Nickel-silver is a third choice but does not in general possess such good properties as either of the other two.

In contact spring design the ratio $\frac{\text{Limit of Proportionality}}{\text{Modulus of Elasticity}}$ is an indication of the effective springiness of the material. This factor for the above three materials is as under :—

Nickel-silver	*Phosphor-bronze*	*Beryllium-copper* *
2·4	4·2	5·8

Contact springs should be of uniform width or of uniform taper, so that stress changes at alterations in cross sections are avoided.

The contact spring assembly used in the L.M.R. arm repeater contact box, employs springs of phosphor-bronze strip with silver contacts riveted on. These contacts are operated by plastic moulded operating cams engaging with manganese bronze nibs for corrosion and wear resistance.

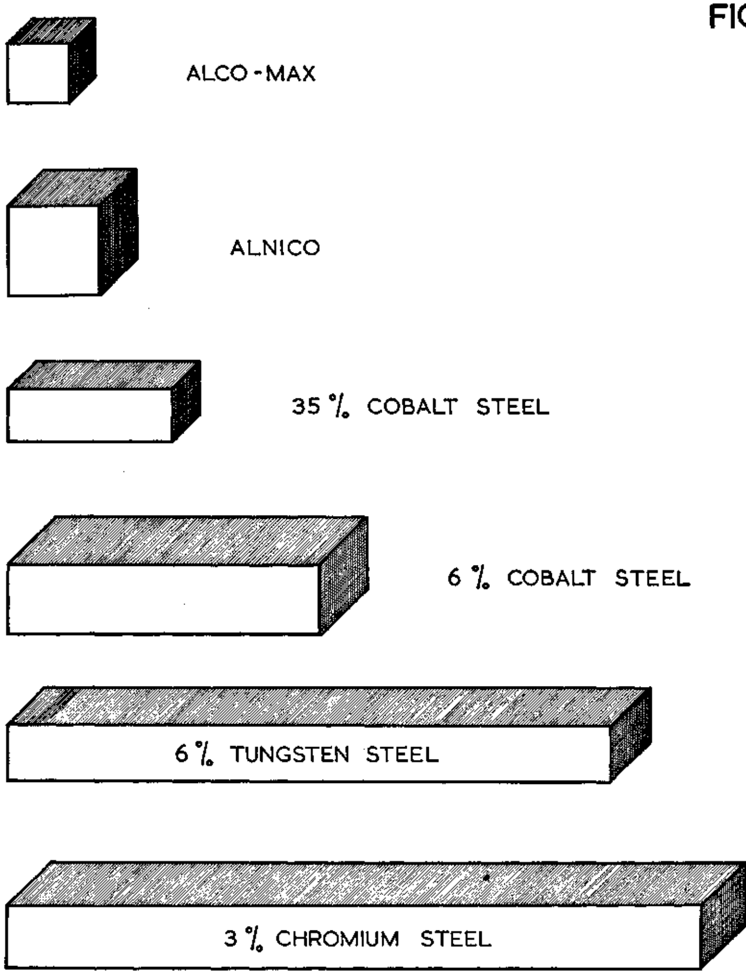
Magnetic Materials

Improved magnetic materials enable a reduction in the size of magnets to be obtained compared with the older magnetic steels.

Fig. 9 shows the relative sizes of magnets of differing magnetic materials, and it will be seen that the aluminium-nickel-cobalt

* "Electrical Contacts," by Dr. L. B. Hunt.

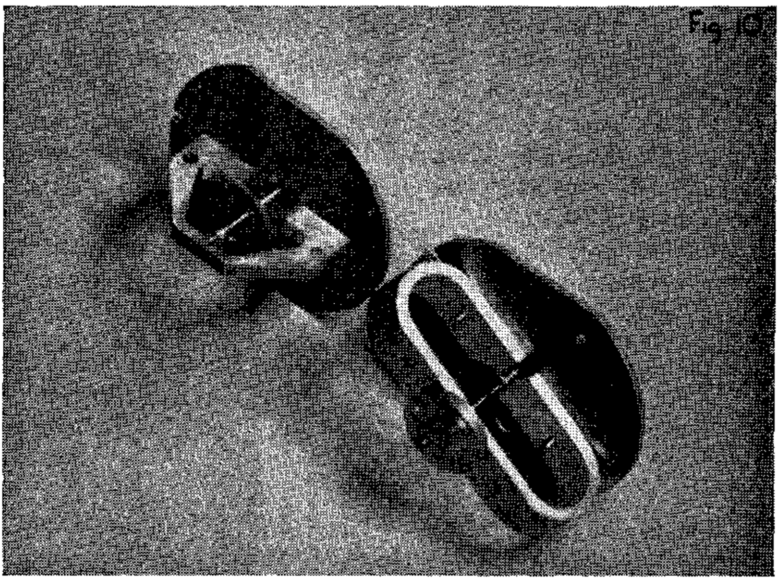
FIG. 9



RELATIVE PROPORTIONS
OF
DIFFERENT MAGNETIC MATERIALS.

magnets are considerably more efficient, enabling a reduction in size to be obtained.*

In practice this reduction may be even greater since the smaller size of magnet often enables the magnetic circuit to be improved. Fig. 10 illustrates an electro-magnetic repeater indicator which formerly employed two matched steel horseshoe magnets to polarise an armature suspended between a pair of control coils. The necessity to match the magnets and the tendency for one magnet to age quicker than the other, thus upsetting the balance of the magnetic field was a defect of the older system which is now eliminated by the use of a single magnetic vane in sintered Alcomax III. The sintering process is attractive for moving magnets since the weight is less than that of a cast magnet and a higher degree of dimensional accuracy can be obtained.



Temperature Sensitive Magnetic Alloys

These alloys which have their Curie points above the normal ambient temperature are used in the electrical instrument industry for temperature compensation and thermal relays, and offer an alternative to bimetallic methods.

* "Magnetic Materials in the Electrical Industry," by B. R. Bardell.

Protective Finishing

Corrosion can be severe and rapid on outdoor apparatus unless a good surface protection is provided. Every precaution must therefore be taken to reduce or inhibit corrosive effects. Rolled steel sheet and sections are particularly prone to deterioration, the smaller items can be given a protective zinc coating by hot dip galvanising, or by cementation. Larger items such as structural steelwork and large instrument cases lend themselves to sprayed metallic coatings such as zinc or aluminium, the surface being prepared by shot blasting prior to spraying. Although this process adds materially to the initial cost, the protection provided greatly prolongs the life of the paint coatings subsequently applied. Coating thicknesses of ·004-in. to ·010-in. are required for complete protection.

Aluminium alloy sheet and cast aluminium alloys containing manganese and silicon do not usually need surface protection due to the protective oxide which forms, but it is essential that contact with metals which are anodic to aluminium is avoided. Where additional protection is required, a zinc chromate primer is recommended with a chlorinated rubber based finishing coat. Contact with alkaline materials such as cement and concrete should be avoided.

Instrument components are readily protected by plating with corrosion-resistant metals such as nickel, tin, cadmium or zinc, passivated or otherwise chemically finished, but the designer should avoid complicated shapes and crevices which could create plating difficulties.

Apparatus Used by Signalmen

It is, of course, of major importance that the indications and controls in the signal box should be of the maximum effectiveness, the luminous indicators should be clear and phantomless under all lighting conditions, the mechanical switches and levers should be of the best possible shape for operation with minimum effort.

The shapes of control knobs, etc., shown in fig. 11, shows the dimensions for manually operated controls which will best accommodate the average hand.*

* "Human Engineering Guide for Equipment Designers," by Woodson.

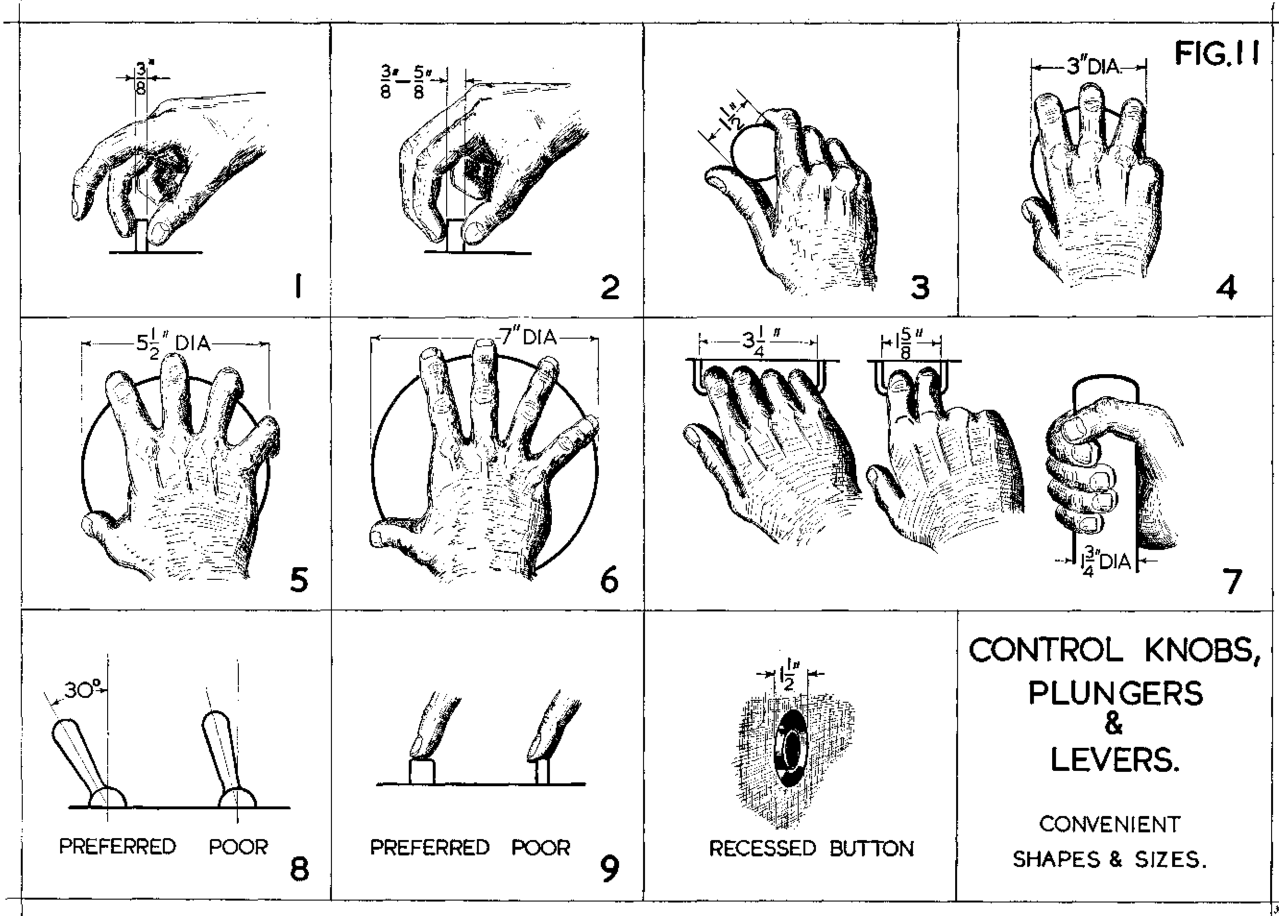


FIG. 11
3/8"
1
3/8"–5/8"
2
1 1/2"
3
3" DIA
4
5 1/2" DIA
5
7" DIA
6
3 1/4"
1 5/8"
1 3/4" DIA
7
30°
PREFERRED
POOR
8
PREFERRED
POOR
9
1 1/2"
RECESSED BUTTON
CONTROL KNOBS, PLUNGERS & LEVERS.
CONVENIENT SHAPES & SIZES.

The maximum force limits for hand operated controls are as follows :—

Small toggle switches ...	... 8-16-oz.
Rotating knobs	... 2 in lb.
Small cranks	... 2-5-lb.
Push buttons	... 10-lb.
Point and signal levers ...	... 250-lb.

Characters displayed in the signal box should be of maximum clarity, and this is ensured if the following proportions are used :—

Stroke Width

The stroke width of black characters on a white background should be about 1/6 of the height of the character.

White characters on a black background can be 1/7 to 1/3 of the character height, the narrower width is permissible due to irradiation effect.

Height-Width Ratio

The height-width ratio of a normal character should be about 3/2.

Maximum Character Height

Viewing Distances (ft.)	*Min. Character Height (in.)*
Less than 1-ft.	... ·09-in.
1-ft.–3-ft.	... ·17-in.
3-ft.–6-ft.	... ·34-in.
6-ft.–12-ft.	... ·68-in.
Minimum space between characters	one stroke width
Minimum space between words	one character width

The Display of Indicators, Controls and Releases

Not only the positioning of the signalman's indicators and instruments is important, but also the overall appearance of the instrument shelf. If the assembled array of indicators, releases, etc., can be neatly packed into cabinets of uniform size, the elimination of confusing and irregular outlines must result in a more pleasing and orderly effect. With these objects in view the instrument arrays for a large power frame, and for a large manual frame were specially designed having the following salient constructional features.

Power Frame

The various indicators, train describers, etc., were housed in a continuous row of cabinets from end to end of the frame. The cabinets were constructed as welded steel chassis with wood tops, the sheet steel facia plates were enamelled olive green colour to match the power frame and carried cream Warerite escutchions. Cream Cobex end panels acted as separators between cabinets.

*Fig. 14 shows several of the cabinets ready for mounting on the frame. The wiring tunnel at the rear of each cabinet can be seen, a wiring duct being fixed in position first, and the cabinets dropped into place over the duct.

Manual Frame

The instrument shelf for this frame is constructed as a welded steel framework in five abutting sections suspended from the ceiling by braced hangers. On the face of the shelf, luminous signal indicators, in some cases combined with route set indicators, and point indicators combined with sealed releases, are all flush mounted on independent panels. On the top of the shelf the train reminders, power off indicators, and luminous block instruments are housed in cabinets of uniform size.

The train reminder cabinets have downward opening front panels, the luminous block instruments have the following features. The luminous T.O.L. and L.C. indicators each contain two telephone type lamps. No " line blocked " indication is provided, the absence of a T.O.L. or L.C. indication being regarded as equivalent to the de-energised needle indication of a conventional needle type block instrument. The three-position commutator is used for both absolute and permissive block instruments. The permissive block instruments have a counting drum enabling a maximum of nine trains to be accepted, which is interlocked with the commutator. The whole commutator and counting drum assembly is one complete sub-assembly carried on a steel plate secured by screws to the main cabinet facia (*fig. 15). As the block instrument bell is concealed, a luminous indicator lights up showing which bell is ringing, and remains lit for 10 secs. after the first ring. The complete instrument shelf assembly is shown in *fig. 16.

* See Inset Sheet No. 1

Electrical Signalling Apparatus

Electrical Route Indicators

*Fig. 17 illustrates a theatre type route indicator. The case is fabricated from spot welded sheet steel, shot blasted and zinc sprayed prior to painting. The hood is retractable and linked to the glass screen covering the front of the indicator. For cleaning purposes the hood can be thrown back, lifting the screen automatically to a horizontal position so that both the screen and the lamp lenses can be reached. The lamp units illustrated in fig. 8 are employed in this indicator with 110-v. or 12-v. lamps and enable back lamping to be carried out.

Repeater Indicators

The small currents and forces which operate the armature of a repeater indicator necessitate careful design to ensure reliable operation. A typical example is the repeater indicator used on the L.M.R. with bearing friction reduced to a minimum by using needle bearings. The spindle is drilled for the insertion of the needle pivot at each end, the pivot being turned down to the correct diameter and length after insertion.

A clearance tolerance on dia. of max. ·0015-in., min. ·0005-in. is required in each bearing and an axial end clearance of max. ·008-in., min. ·005-in. To obtain these tolerances the spindle pivots are turned to limits of +·016-in.
+·0155-in. and the pivot bearings drilled and burnished to limits of +·017-in.
+·0165-in. The axial end clearance is obtained without close limits on the axial dimensions of pivots and bearings by the use of shims ·002-in. thick.

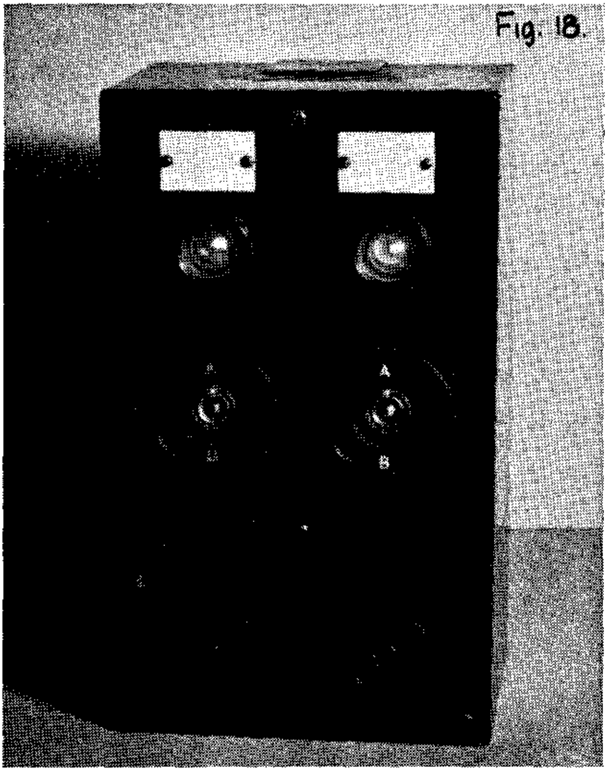
The moulded case for this instrument is dustproof and sealed, the connecting terminals being on the exterior of the base, so that the instrument is immune to dust and dampness.

Electrical Repeater Indicators

Oil Lamp Light Repeater

This repeater as shown in fig. 18 is housed in the plastic moulded case previously described. Each case accommodates two repeater units, comprising a buzzer, relay, two-way switch, indicator light and test plunger. Operation of the test

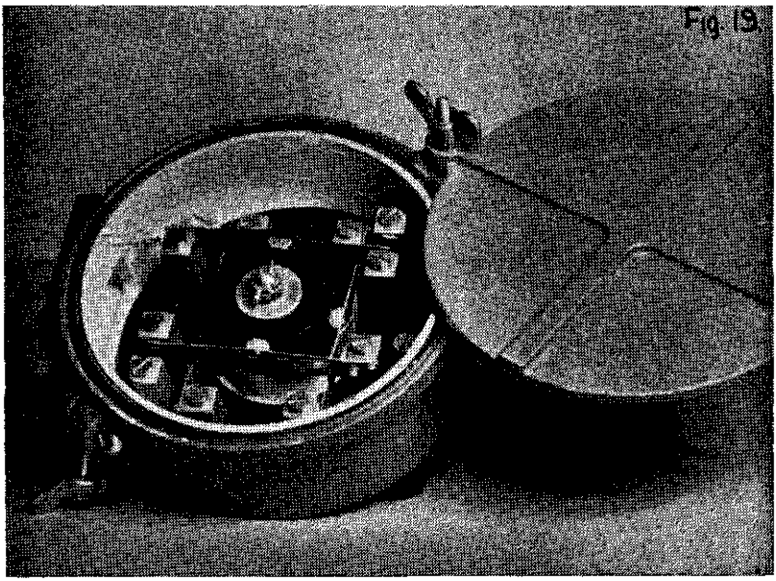
* See Inset Sheet No. 2



plunger energises the light in each unit if the signal oil lamp repeated by that unit is burning correctly. While the oil lamp is burning the pyrometer contacts in the lamp case are made and energise the relay in the repeater unit. Failure of the oil lamp will cause the pyrometer contacts to open, de-energising the relay thus operating the buzzer and so calling the signalman's attention to the fault. The signalman then disconnects the buzzer by operating the two-way switch. When the fault is rectified the pyrometer contacts again energise the relay which in turn completes the buzzer circuit. The buzzer is then disconnected by returning the two-way switch to normal. Several repeater units can be mounted on top of each other or side by side as required, using a common test plunger and buzzer unit.

Mechanically Operated Electrical Contacts
Arm and Weight Bar Repeater Contact Box

Fig. 19 shows the assembled contact box, the case already illustrated as an example of aluminium-silicon alloy is provided with a gasketed lid. The contacts are cam operated giving an " ON " indication within 5° from normal, and an " OFF " indication between 37½° and 65° from normal, the intervening angle



giving a wrong indication by contact disconnection. As there is practically no rubbing action with these contacts they are silver-silver.

To insure against seizure due to corrosion or lack of lubrication, the contact box spindle is of silver steel carried in bearings fitted with oil retaining bushes. The wiring inlet is sealed by bitumastic compound.

Catch Handle Contact Boxes

To restrict the energising of electric lever locks to a minimum, a catch handle contact box is used operated by the tappet of the lever frame which is of the catch handle locking type.

The first action of raising the catch handle prior to moving the lever from normal completes the normal lock circuit and enables the lock to pick up, releasing the lever and becoming de-energised by the circuit controller when the lever moves from the normal position. When the catch handle is raised with the lever in the reverse position the contact arm in the contact box moves the other way and completes the reverse lock circuit, thus energising the lock momentarily to release the lever from the reverse position. If the lever is controlled by a normal lock only the reverse contacts are of course disconnected. This contact arrangement reduces the period of energisation to a minimum and in conjunction with the circuit controller ensures that the lock bolt is never forced down while the lock is energised. This contact box is shown in fig. 20.

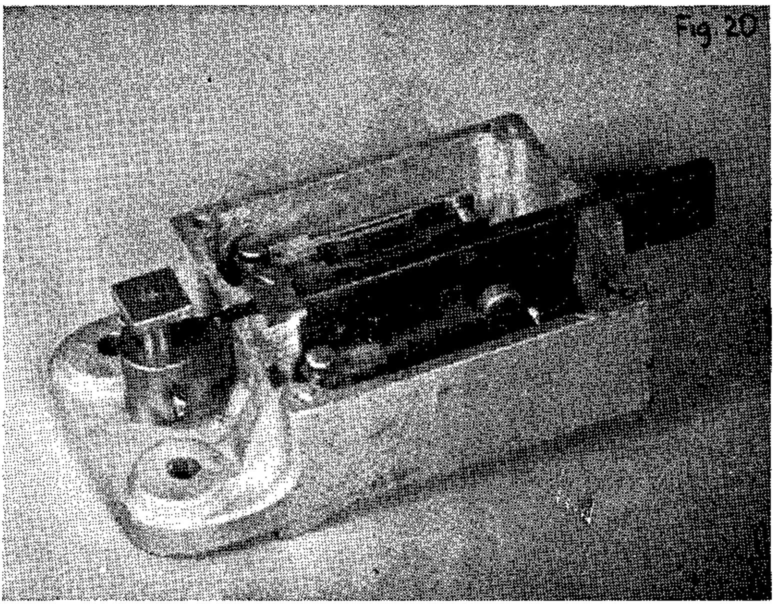
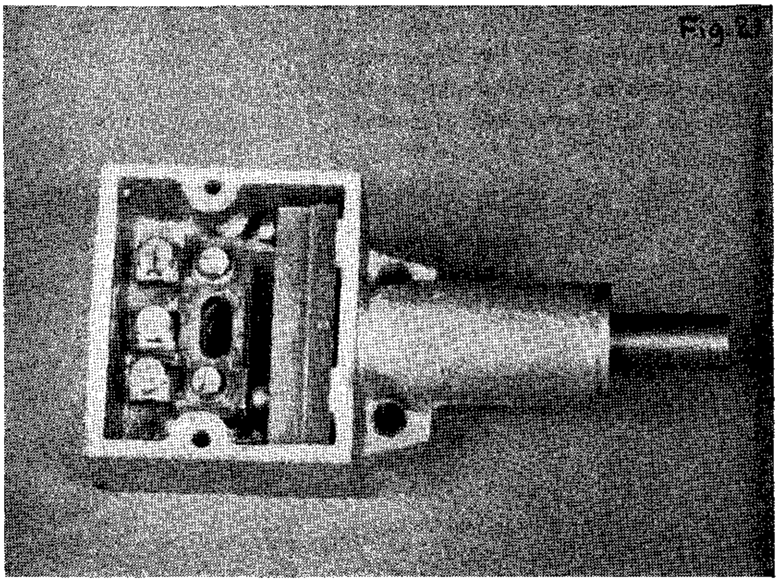


Fig. 20

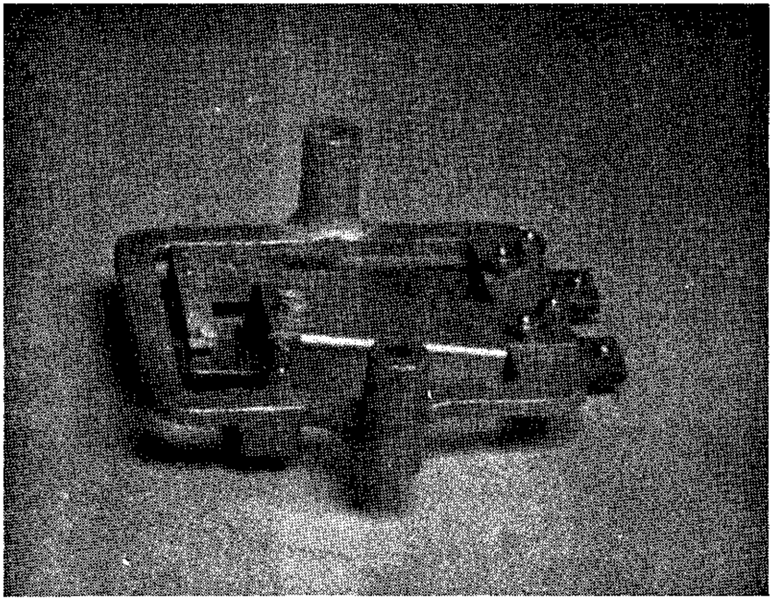
Lever frames employing direct lever locking with no catch handle connections, which can be utilised to operate this type of contact box, can be fitted with another type of box which is operated by a spring loaded plunger lifted by the catch block. Fig. 21 shows this box. Selection of N and R contacts is effected by using as a contact medium, a phosphor-bronze ball which is located in a race in the box. When the lever is normal the ball rests at one end of the race, and is clamped between the upper and lower contact members when the catch handle is raised, being held in this position during the travel of the lever from N to R and on being released by the catch block dropping, runs to the other end of the race ready to make the reverse contact if required when the handle is again lifted.



Thermally Operated Electrical Contacts
Oil Lamp Repeater Pyrometer

The bimetallic pyrometer shown in fig. 22 is positioned directly in the lid of the oil lamp. The pyrometer frame is a gun-metal casting carrying two bimetallic contact strips, one located directly in the hot gas stream from the burner, and the other in the cooler air outside the stream. The use of two bimetallic strips ensures compensation for all ambient temperatures, the cover over the hot strip being provided to protect it from down draughts. The contacts are set to a gap of ·050-in. to ·070-in. when cold.

Some difficulty with the fixing screw insulation bushes due to the high temperature near the flame has been overcome by the use of fluorocarbon.



Electric Locks and Circuit Controllers

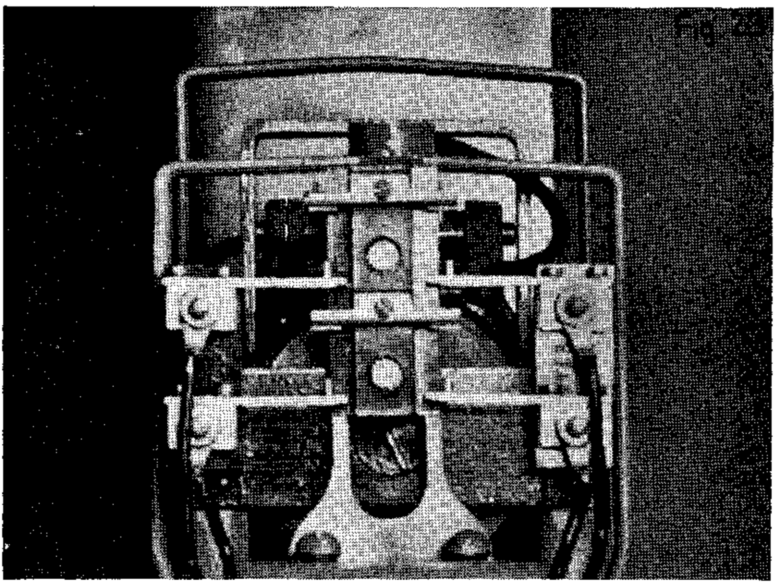
The electric lock and circuit controller described below is used in the vertical position and operates on 12 volts with a pick-up voltage of approximately 7 volts and drop-away of approximately 2 volts.

All locks are fitted with proving contacts and force downs. An illustration of the proving contact arrangement is shown in fig. 23. It will be seen that short bars carrying silver contacts are carried in a moulded plastic block secured to the lock bolt which makes contact with horizontal contact springs mounted on the casting. The contact is under direct vertical pressure and there is no side pressure which could reduce the effective gravitational force restoring the bolt. The force down feature consists of a stud projecting on each side of the lock slide, which engages with bevelled projections at the bottom of the lock bolt, forcing the lock down into the locking notch. The action of the force down prevents the use of " tight " locking faces, some freedom of movement being necessary to enable the force down to operate.

In addition it is necessary to cut back one of the lock notches past the force down stud to permit the bolt to drop in to the notch when first inserting the slide in the lock. This extra length of lock notch can create undesirable slackness in the locking since maladjustment of the slide can increase the distance between the bolt and the locking face of the notch. To prevent this a removable stop piece is provided, secured in the lock slide which is fixed in position after the slide is inserted in the lock, thus maintaining minimum length of lock notch. To remove the slide it is necessary first to remove the stop.

The circuit controller drive is through a slot on a cam-plate secured to the slide, guiding a stud carried on the controller pinion wheel.

The controller drum is geared to the pinion by a gear wheel giving a movement on the controller drum with a 2·1 ratio. The



controller segments are carried on bakelite moulded cams. The bearings are provided with oil retaining bushes. The sheet metal covers are secured by triangular headed screws. The controller contacts are copper-phosphor bronze with a good wiping action.

Electrical Signal Selector

*Fig. 25 shows an electrical selector which employs the standard electric lock movement with a special lock bolt which engages

* See Inset Sheet No. 2

with one slide when the lock is de-energised and the other slide when energised.

The selector is employed to save levers and is used to enable one lever to operate main and subsidiary signals.

The signal lever is connected to the centre slide which carries a pinion engaging with a rack on each of the outer slides. When the lever is operated the fixed slide causes the pinion to rotate as the centre slide moves, operating the free slide.

Mechanical Signalling Apparatus

Electric Lock and Circuit Controller Mountings for Manual Lever Frames

It is essential that Electric Lever Locks and Circuit Controllers are rigidly supported, and in a position which provides maximum accessibility for maintenance. Fig. 26 shows the supporting framework for electric locks and controllers in the lower floor of a signal box with a manual lever frame. The locks and controllers are carried on pre-drilled racks bolted to upright stanchions, and are readily accessible from the walkway.

The lever frame bed girders, and the lock rack frame, form one complete bolted assembly so that there can be no relative movement between the locks and levers. All the structural members are in standardised bay lengths and heights, and are assembled as required for any size of lever frame and any height of signal box in the standardised height range.

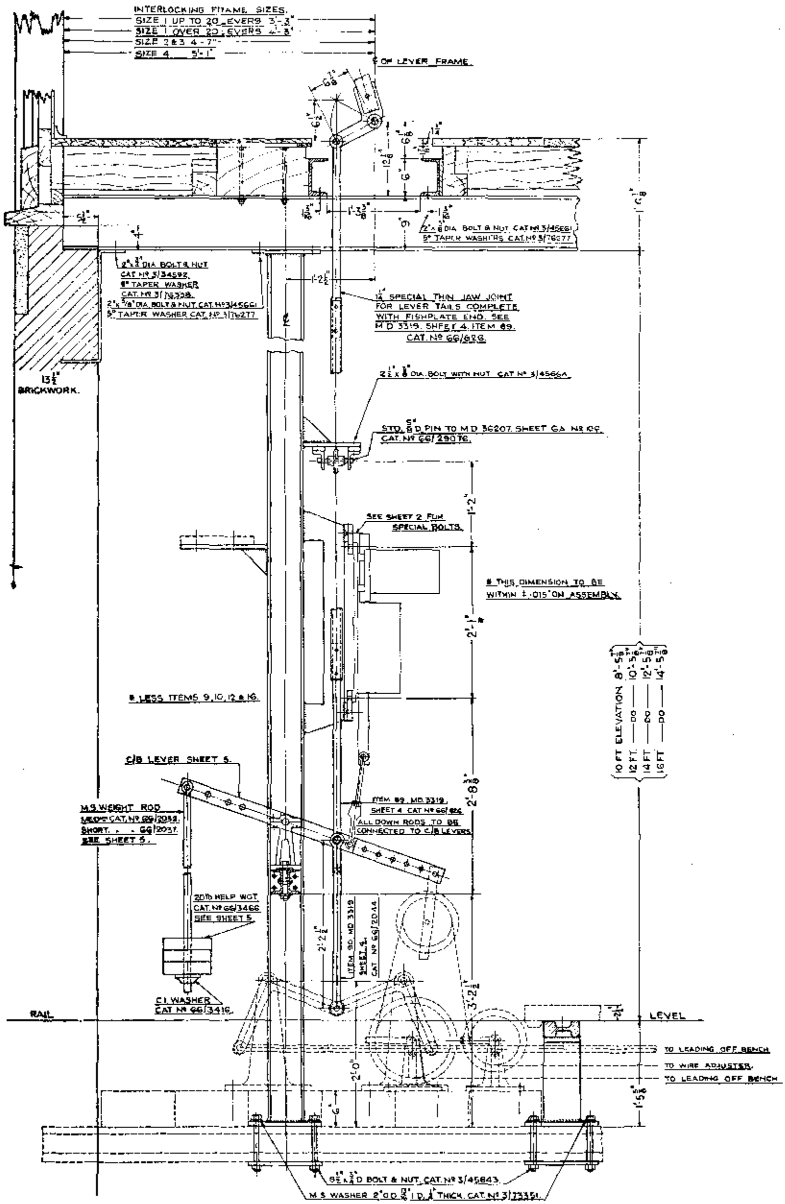
Rubber Applications

Some applications of rubber in mechanical apparatus are described below, where grease and oil are present, oil resistant Neoprene is used.

Semaphore Arm Spring Buffers

Rubber bonded bolts are now in general use for the U.Q. signal arm, superseding the old spring buffer. Arm bounce is reduced with this type of buffer which also requires no maintenance.

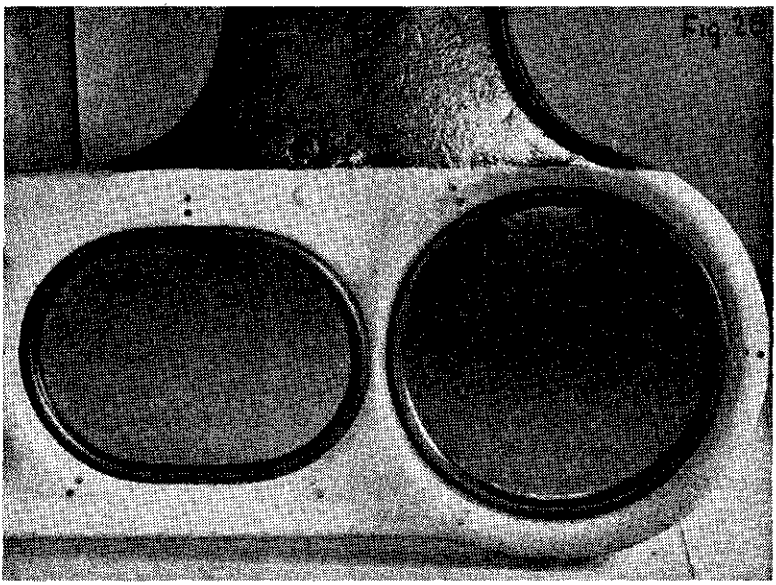
FIG. 26



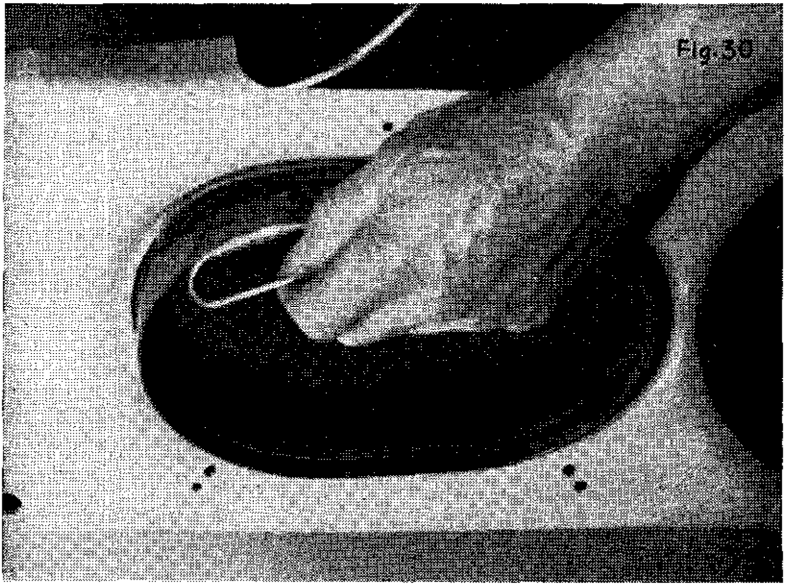
INTERLOCKING FRAME SIZES.
SIZE 1 UP TO 20 LEVERS 3'-3"
SIZE 1 OVER 20 LEVERS 4'-3"
SIZE 2 & 3 4'-7"
SIZE 4 5'-1"
℄ OF LEVER FRAME.
2" x ⅝" DIA. BOLT & NUT CAT. Nº 3/45661
5" TAPER WASHERS CAT. Nº 3/76077
2" x ¾" DIA. BOLT & NUT CAT. Nº 3/34592.
5" TAPER WASHER CAT. Nº 3/76328.
2" x ⅝" DIA. BOLT & NUT CAT. Nº 3/45661
5" TAPER WASHER CAT. Nº 3/76277
13½" BRICKWORK.
1¼" SPECIAL THIN JAW JOINT FOR LEVER TAILS COMPLETE WITH FISHPLATE END. SEE M.D. 3319. SHEET 4. ITEM 89. CAT. Nº 66/826.
2½" x ⅝" DIA. BOLT WITH NUT CAT. Nº 3/45664.
STD. ⅝" D. PIN TO M.D. 36207. SHEET GA Nº 100. CAT. Nº 66/29076.
SEE SHEET 2 FOR SPECIAL BOLTS.
* THIS DIMENSION TO BE WITHIN ± ·015" ON ASSEMBLY.
* LESS ITEMS 9, 10, 12 & 16.
10 FT. ELEVATION 8'-5⅝"
12 FT. —DO— 10'-5⅝"
14 FT. —DO— 12'-5⅝"
16 FT. —DO— 14'-5⅝"
C/B LEVER SHEET 5.
M.S. WEIGHT ROD MEDIUM CAT. Nº 66/2052. SHORT. " " 66/2037. SEE SHEET 5.
ITEM 89. M.D. 3319. SHEET 4 CAT. Nº 66/826
ALL DOWN RODS TO BE CONNECTED TO C/B LEVERS.
20 lb HELP WGT. CAT. Nº 66/3466 SEE SHEET 5.
ITEM 90. M.D. 3319 SHEET 4. CAT. Nº 66/2044
C.I. WASHER CAT. Nº 66/3416.
RAIL
LEVEL
TO LEADING OFF BENCH
TO WIRE ADJUSTER.
TO LEADING OFF BENCH
9½" x ¾" D. BOLT & NUT. CAT. Nº 3/45843.
M.S. WASHER 2" O.D. ¾" I.D. ⅛" THICK. CAT. Nº 3/73351.

Semaphore Arm Glazing

Fig. 28 shows an U.Q. signal spectacle employing a rubber glazing ring now used on the L.M.R. for mounting the spectacle glasses in the spectacle. This glazing ring eliminates the old putty and rivet method of fixing the spectacle glasses and makes glass replacement *in situ* simple. In addition by providing a resilient cushion between the glass and spectacle, stresses due to differential thermal expansion are eliminated and the physical shocks received when the arm strikes the buffer are cushioned by the ring, and so the glasses can be expected to have a considerably longer life. This method of glazing is general in the automobile industry, and a standard extruded automobile glazing strip was used at first, the strip being formed into rings of the correct size with a scarfed and vulcanised joint. Special one piece mouldings have now been obtained which eliminate the joint.



To facilitate the glazing process a jig and former are used to fit the ring on to the glass, the rubber flanges being held inwards by the former which is of the correct shape to pass through the aperture in the spectacle. The glass, ring and former are applied to the spectacle, the former passing through the aperture is then pulled off releasing the rubber flanges which grip the spectacle and hold the spectacle glass securely in position. Fig. 30 shows the former being removed from the spectacle leaving the glass secured by the rubber glazing ring.



Signal Structures

Straight Posts for Semaphore Signals

Tubular steel is now firmly established as the best type of post for these signals, internally treated with bitumastic compound to prevent corrosion. The smooth external surface is easy to paint and there are no crevices in which corrosion can form. The internal surface is, however, difficult to inspect and complete insurance against internal corrosion can be obtained only by fully sealing the post at top and bottom, and attaching the fittings either by clamping or stud welding, eliminating all holes in the post and carrying any wiring on the outside. Where the post is buried in the ground a spun concrete sleeve gives protection and additional ground bearing surface.

Bracket Structures for Semaphore Signals

Tubular stems are suitable up to certain heights after which fabricated R.S. Channel stems are employed. For the best appearance a constant ratio of doll length to stem length is desirable, land ties are fixed to the stem below ground and in addition a side guy. Where the side guy is difficult to provide due to adjacent tracks, concrete foundations of sufficient depth to ensure stability are necessary.

Semaphore Gantry and Cantilever Signals

Fully welded Warren girder construction is advantageous for these structures, the girders being bolted to the stanchions. A typical girder is shown in *fig. 31. Balance lever assemblies are mounted within the girder on their respective dolls and a small lower landing provided for access.

Colour Light Signals

Tubular steel posts are in general use for straight posts and small offsets, and a standardised range of colour light signals is shown in *fig. 32. †Fig. 33 illustrates a bracket signal of 15-ft. 6-in. overhang which has been designed as a fabricated R.S. Channel stem with an R.S. Channel girder which is stiff enough to dispense with brackets or tie rods. A large gusseted seating being provided to attach the girder to the stem.

Large Cantilevers and Gantries

†Fig. 34 shows the deck of a large cantilever signal for an overhead electrification scheme, protective netting is seen which was required by the proximity of the high voltage traction wires. A special feature of this structure is its open top permitting a centre gangway and an open platform at the end giving space for unit fixing and maintenance. This structure being in effect a braced " U " girder required careful design to ensure that all forces likely to be imposed upon it were adequately met by the bracing. †Fig. 35 shows the complete structure.

‡Fig. 36 shows a colour light gantry erected at Euston and carrying the up-fast departure signals. Of welded Warren construction, it will be seen that the anchorage provided by the wall seating enables corner brackets to be omitted on the left-hand stanchion, a simple bolted joint being used. Asbestos cladded steel smoke plates were fitted over the two right-hand roads, and sheet steel over the two left-hand roads for life comparison purposes.

* See Inset Sheet No. 3 † See Inset Sheet No. 4 ‡ See Inset Sheet No. 5

The former show no sign of deterioration and are now in general use.

*Fig. 37 shows a colour light gantry of 55-ft. span employing Castellated joists for both stanchions and girder. This method of construction now becoming increasingly used for light structural steelwork, is very suitable for signal gantries. *Figs. 38 and 40 show the Castellating process. By this process a 10-in. × 3-in. R.S. Channel with a section modulus of 16·53 is increased to a 15-in. × 3-in. R.S. Channel with a section modulus of 25·64, with no increase in weight.

This type of construction is very economical in first cost, in spite of the addition of shot blasting and aluminium spraying prior to painting which should materially reduce maintenance costs.

Mechanical Detection of Turnouts

Where a number of signal wires require to detect several turnouts in series, and the run contains a number of diversions, detector slide replacement is assisted by weighted detectors, and a multiple weighted detector containing a maximum of six signal slides is available. The signal slides control a single weighted detector slide, thus the blades connected to the switches only require cutting for one slide. The signal slides in one multiple detector must all require to detect the points in the normal position or to detect the points in the reverse position. Two multiple detectors are required to obtain both normal and reverse detection of the points.

This detector is illustrated in †fig. 41 and is used for 3-6 slides, for 1 or 2 slides a two-way weighted detector is used.

Electrical Depression Bars. Special Fixing in front of Jaeger Buffer Stops

An example of a special fabricated rail attachment for an electrical depression bar is shown in †fig. 42 and was installed in front of the Jaeger type buffer stops on Nos. 1 and 2 platforms at Euston.

This type of buffer stop uses the resistance to motion of the drag rails and sleepers to absorb the impact on the stops, a heavy impact can push the stops back several feet together with the

* See Inset Sheet No. 6 †See Inset Sheet No. 7

drag rail and sleepers. Damage would be caused to depression bar rail clips attached in the normal way to the stock rails and it was, therefore, decided to attach the depression bar to the drag rails, using fabricated clips welded to the rail as shown in *Fig. 43. These depression bars have survived several movements of the buffer stops without material damage.

Facing Point Locks

*Fig. 44 shows a facing point lock of conventional pattern with the addition of a snugly fitting galvanised steel cover. The cover is secured by resilient bushes and is snapped into position under foot pressure. A smart pull on the end of the cover will release it. This type of cover gives improved weather protection and minimises the obstruction of the track by the lock thus reducing the possibility of damage by lowered locomotive water scoops or dragging equipment

Conclusion

The foregoing examples illustrate a few selected current and recent designs of signalling apparatus used for new works and for general signalling requirements on the L.M. Region. In these days of high production and maintenance costs, the importance of good design cannot be exaggerated in reducing operating costs and ensuring reliability.

The designer must keep abreast of current developments in materials and processes, the plastics industry particularly can be expected to produce new and improved materials as a result of the continuous research in this field.

To conclude this paper the author cannot do better than give two quotations from an article which recently appeared in *The Engineer*†. Firstly : " Take care of the design and the manufacture will take care of itself " and secondly : " Prove all things, hold fast to that which is good."

Finally, the author must express his thanks to Mr. S. Williams, Signal Engineer, L.M. Region, under whose direction the designs described have been carried out, for permission to present this paper, and to those colleagues on the Signal Engineers' staff who have given the author so much valuable advice and assistance.

* See Inset Sheet No. 7

† Drawing and Design," by H. Clausen.

DISCUSSION

Opening the discussion, **Mr. J. C. Kubale** said that a good deal of the equipment described in the paper had been in use for a great number of years. There was undoubtedly scope for development and the Author had indicated very clearly some of the improvements carried out on the London Midland Region. The paper was valuable in the practical examples given regarding both methods of manufacture and materials which that Region had found satisfactory. There seemed to be ample scope for the ingenuity of the young signal engineer in superseding some of the existing designs by modern equivalents, perhaps thereby cheapening installation. From some of the illustrations shown, for example, those of block instruments, the construction would appear to be more expensive than the use of simple light indications with push button and relay circuiting to accomplish the same results.

He did not agree with the two maxims with which the author ended the paper. Firstly, one could not leave manufacture to take care of itself, as one had to take care of both design and manufacture. Secondly : " Prove all things, hold fast to that which is good " could result in stifling valuable development.

Mr. J. E. Mott said that the wide scope of the paper made it a valuable summary of design points and it would serve as a very useful reference, not only to designers, but also to users. It enumerated some general principles of design but there was a basic essential that must be appreciated. There must be quantity production in order to take advantage of modern techniques that were available, and that called for standardisation and uniformity between users, not only in Great Britain but also on railways overseas.

To be economical, a design must not include more than is really necessary. In considering the servicing of apparatus it was advantageous to have renewable bearings, but they increased the manufacturing cost of the article. It was most essential to have good specifications and they should be included in a review of designs.

The paper suggested that use should be made of all the latest techniques in the way of plastic materials and so on. This gave rise to the thought that perhaps the industry itself was best suited to provide most new designs, although it was necessary, of course, to have access to the railway for proving new designs and new techniques.

Reference had been made to "breathing," and Mr. Mott recalled seeing in North America some machines produced with breathers over which adhesive tape was placed. In one location the tape would be left on, while in another it would be pulled off ; depending on the humidity of the locality.

It was a requirement today for point machines to be waterproofed entirely, but it was very difficult to provide for breathing and at the same time have a machine that could be flooded and still operate. He invited the author's comment on this matter.

With regard to aluminium alloys, Mr. Mott stated a case in which an overseas manufacturer produced some searchlight signals, using aluminium die castings. The die castings showed signs of ageing after a week ; causing distortion and holding the vane in the wrong position. He mentioned this in order to illustrate the great care which had to be taken in the choice of materials. In regard to control knobs, plungers, and the like. It would seem that these would have to be related to the type of signalman accustomed to mechanical frames, or to those accustomed to power frames or relay interlocking panels, because the approach would be very different. In years to come, there would most likely be very much more in the way of plungers, keys and the like.

Mr. B. Reynolds said that a list of main design requirements should emphasise that it is fundamental that any failure must create safety conditions. He thought that this point had been covered in the illustrations, but ought to feature in the wording of the paper.

Production methods were of great interest, but in such cases as London Transport, where they could not get production on any grand scale, he found the temporary expedients put forward in the paper of even more interest ; such as the fabrication method by which a design could be thoroughly explored before expensive moulds and tooling were made.

Regarding the suggestion that more multi-pin plugs should be employed, one would have to be certain that these would maintain good contact with all their pins, before recommending them for general use. He felt that a good deal more could be said concerning the use of polyester resins which had many applications and on London Transport had been put to very good use.

The author mentioned that it was London Midland Region practice to employ adequate terminal blocks, and Mr. Reynolds asked if reference to soldered joints had been omitted for any reason.

Two points of particular interest were the fitting of the spectacle glasses by means of the rubber glazing ring, and the method of castellating joists. Regarding the latter, which seemed to have a very low first cost, after seeing the process illustrated on the slides, he was inclined to think that the method of cutting might be more costly in some cases.

Mr. T. S. Lascelles referred to the signal repeater indicator in which the Spagnoletti axle had been replaced by a permanent magnet on a spindle, and said that this reverted to a design of many years ago. It was 82 years ago that the Spagnoletti induced needle was brought in to overcome the danger of the reversal of the polarity of permanent magnets, due to extraneous surges. He asked if one could now be sure that modern permanent magnets were immune from reversal, by surges produced by induction, lightning effects and so on? If so, he agreed that the Spagnoletti needle could be superseded.

Mr. J. F. H. Tyler said that the paper had come at an opportune moment, all signal engineers were engaged in development in one form or another, particularly in respect to designs resulting from modern materials making some of the apparatus smaller than it used to be. It was a long term matter and he asked if the author had given thought to soldered joints and the question of wiring connections, because it was largely on these that the making of smaller apparatus would depend.

On the question of condensation, he stated that trials had been made with cork inside the lid of the point machine, but had proved to be of no value. One very effective method had been the provision of a ventilating hole in one side of the gear case and another at the other side, providing a direct draught through the case and on these condensation troubles had disappeared.

With regard to the flat bottom bar with flat bottom switch, he enquired if experience had shown that the bar could be kept up to the rail satisfactorily and if it entailed cutting of the flange.

From the description of the facing point lock cover, he could not be sure if the cover held the blade in position. He was interested in the reference to weighted detectors and felt that they were not altogether satisfactory.

With regard to colour-light brackets, while designing one at Reading some years ago it was found that the torsion of the main stem was quite considerable, and they had incorporated a special branch to overcome it. He enquired if the design shown by the author had been given full consideration in this respect.

As cranks and compensators lasted 15 or 20 years, he asked if it been shown that replacement of bushes was really worth while.

Mr. H. J. N. Riddle, referring to temperature sensitive magnetic alloys, enquired if any of them had actually been used in railway service and if the author could give further details concerning them.

The author had said that when straight posts for semaphore signals were buried in the ground, a spun concrete sleeve gave protection and additional ground bearing surface. He assumed that the concrete sleeve was a loose or sliding fit on the post and not spun on to the post itself; but if it were a loose fit, there would be a space for water to run down between the concrete and the post. He enquired if bitumastic cement were placed between the sleeve and the post.

Mr. R. J. Post referred to the author's statement that characters displayed in the signal box should be of maximum clarity, but had not mentioned the form used. Dr. Mackworth of the Applied Psychology Research Unit of the Medical Research Council at Cambridge University had determined that figures constructed with straight lines and sharp angles could be read more quickly and accurately than figures constructed from curves, also that the height/width ratio of the letter or figure should be approximately 1 : 1, nothing being gained in speed or legibility by increased height. These observations and some other figures appeared in The Institution of Electrical Engineers' paper No. 1152. He asked whether the author's suggested ratios had been based on any experimental data.

Mr. A. Cardani, referring to main design requirements, said that a high degree of reliability was essential, associated with a fixed dependable life, after which apparatus would be scrapped. This would assist the introduction of mass production methods for the purpose of cheapening the cost.

Regarding the reference to breathers merely requiring a fine mesh screen to prevent the entry of insects and dust, insects had appeared inside relays causing " right side " failures, by getting squashed between the contacts, but whether the eggs were deposited before the wire mesh was put in was not known.

The chief advantage of the use of multi-point plugs would be where equipment was frequently plugged in and out, and he thought that this would not be of great value in the wiring of a relay room which, once installed, was not likely to be disturbed. Great care would have to be taken in the soldering of the connections.

Under Maintenance and Inspection, it was stated that open doors should not foul the structure gauge, and he asked if it would be more flexible to state loading gauge as one hoped that doors would not be left open. He appreciated that fine limits could be obtained without machining by the use of high tensile steel and asked whether this material was confined to locking dogs on the bars where it seemed that strength was more necessary.

Regarding the use of steel bar magnets in indicators, he thought that these might be more sensitive to stray fields than those used with the conventional Spagnoletti movement.

Temperature sensitive magnetic alloys might find a valuable application in connection with thermal time element relays as they were capable of very accurate timing.

The method of glazing semaphore signal spectacles did not, of course, touch the problem of wilful damage such as by stone throwing and he enquired if other materials had been tried and found unsatisfactory.

Regarding bracket structures for semaphore signals, it had been said that tubular stems were suitable up to certain heights, after which fabricated R.S. Channel was employed, and he asked if the author could state the height referred to

He asked for more information concerning the type of base that was used with posts for colour-light signals, and if it was cast iron bolted on to a concrete base, or clamped on a concrete base buried in the ground.

Fig. 33 showed two signals applying to parallel roads. These were the same height, but the one on the left-hand side could have been brought down to optimum height at rail level, and if that were the case, he considered that the sighting would be improved. He asked if the gusset on the bracket structure was riveted or welded. He was not in favour of land ties, especially with bracket signals with any degree of overhang.

Mr. V. S. King said that a problem arose when one called for designs that were suitable for many terms of servicing and at the same time wanted to introduce all improved methods, materials and techniques as they came out. Such methods changed frequently and when servicing came about there was the obvious difficulty with spare parts, unless one component fitted the next design. That led to the trouble of components for previous designs which were required in small quantities as spares but which were obsolete from the manufacturers' point of view.

Mr. R. O. Willmott said that recent trials had been made to overcome condensation by applying a thin sheet about $\frac{1}{4}$-in. above the lid of the detector box on a point machine, leaving out all breathing holes. Experiments had been going on for a short time but appeared to be satisfactory.

Mr. L. G. Smaldon thought that the use of shims was not really necessary as the British Standard Specifications were quite adequate.

Tubular signal posts could not be painted internally, but he believed that some undertakings such as gas and water had them galvanised. Much could be said in favour of rolled steel posts and for rails bolted together. He knew of many that had been in service for many years and showed no sign of decay.

The **Author**, *in reply* to *Mr. Kubale,* said that development was taking place on the lines of simplification and the reduction of operations to minimise the complexity of apparatus handled by the signalman.

Regarding criticism of the statement that if the design were taken care of, the manufacture would take care of itself ; the statement really meant that if the design was wrong the manufacture could never be right, but if the design was right most of the manufacturing difficulties would disappear.

In reply to Mr. Mott. The necessity for quantity production was understood and quantities were a problem in the signal engineering world. High quality was essential but if the price of apparatus was too high it could not be used. A manufacturer had to employ the most favourable production methods to suit the circumstances, and there was no doubt that good specifications were of great value.

Breathers were a very controversial subject. The question of condensation had never been fully solved, and its effects depended so much on local conditions, which varied not only from country to country, but almost from county to county.

He was interested in Mr. Mott's comments on the distortion of die castings due to ageing.

The data in the paper with regard to control knobs referred to a publication by Woodson, who did a considerable amount of research in the field of sizes of knobs and forces required to operate them. It had particular application to operators for radar equipment and so on, but seemed applicable to operators in signal boxes.

In reply to Mr. Reynolds, apparatus must fail to safety and the term "highest degree of reliability" was intended to cover that.

Good contacts on multi-pin plugs were a necessity, which must ensure reliability in all circumstances and plugs were obtainable to give that feature.

He had made only a passing reference to polyester resins, because they were not in current use on the London Midland Region. But he was interested to learn of their application on London Transport.

Soldered joints required very careful making with non-corrosive fluxes. There were alternative types of joints which were being tried out and results were being examined with great interest.

Castellating had proved to be really economical. The particular illustration shown was of an actual structure on which the saving in production costs amounted to approximately twenty per cent.

In reply to Mr. Lascelles. Full service tests had been carried out with the Alcomax II magnets with excessive surges, in the reverse direction and the characteristics of the indicator were unaltered. The new magnetic materials fulfilled these requirements.

In reply to Mr. Tyler, regarding condensation in point machines. With the machine right down on the ground, it was impossible to provide an outlet, and at the same time to keep water out. Due to atmospheric conditions some condensation would surely take place.

The clip on the facing point lock bar was securely held up to the rail. Rail drilling was completely dispensed with and the clip was tight and immovable. The facing point lock was machined down to the top of the lock bolt, but there was a strap riveted to the top and a cavity in the cover to clear the strap. The cover itself did not hold the bolt in position.

Weighted detectors were not favoured in all fields, but they were usefully employed on the London Midland Region under the conditions which he had described.

Cranks and compensators had been bushed for some time and were returned for re-bushing repeatedly to the Crewe workshops. This had proved to be economical.

Torsion plates had been incorporated on the bracket signal stem.

In reply to Mr. Riddle. He had not actual service experience with temperature sensitive magnetic alloys, but had carried out tests, sufficient to indicate that it was advantageous to use them in their particular field.

With reference to the spun concrete sleeve, the space referred to was filled with cement and the difficulty of maintenance was overcome.

He expressed interest in Mr. Post's remarks on the Cambridge data on character sizings, and stated that he had used Woodson's data.

In reply to Mr. Cardani. Reliability did not mean only long life, and he, the Author, associated it more with the absence of wrong side failures.

Multi-point plugs, even for occasional connection and disconnection, saved the possibility of a wrong connection. It was, of course, essential to use a connector of complete reliability.

Regarding the suggestion concerning the loading gauge, he did not think that this would be approved by the Gauge Clearance Department on his Region.

The high tensile steel had been used for the locks to give increased wear resistance.

He agreed that bar magnet indicators were basically more sensitive to extraneous fields than the Spagnoletti movement, but stated that they were adequately shielded.

Referring to the semaphore signal spectacles, experiments had been carried out using a toughened material which was found to be very effective.

Tubular stems for bracket signals were suitable for heights up to 25-ft. Fabricated steel, welded, gusseted bases were used for colour-light signals. The height of the signals shown in fig. 33, were fixed for particular sights.

Land ties had been used by the London Midland Region for many years quite successfully.

In reply to Mr. King. Component interchangeability was essential and he realised the problem of providing spare parts for the older designs.

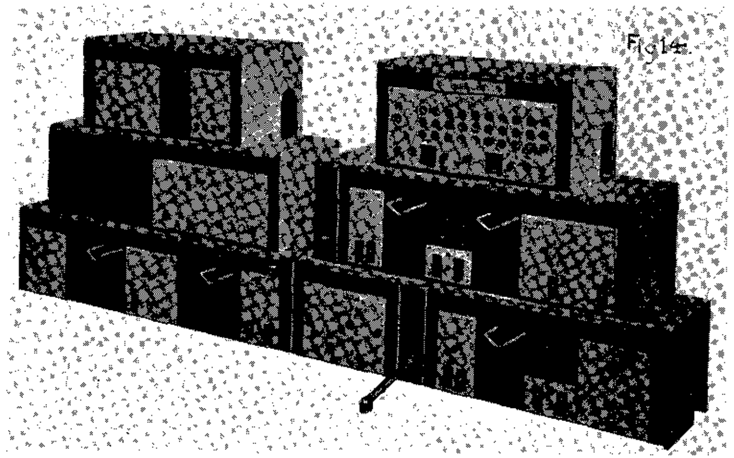
He was most interested in the experiments described by Mr. Willmott and would welcome more information on the subject.

In reply to Mr. Smaldon. Shims were necessary and an economical means of compensating accumulated tolerances.

Internal corrosion on tubular posts was overcome with bitumastic paint. Rails bolted together lasted indefinitely, but were a heavy method of construction.

The **President**, moved a very cordial vote of thanks to the Author, and said that the paper showed very clearly the importance of the design of signalling apparatus. He also congratulated the Author on the excellence of the coloured slides, which enhanced the value of the paper very considerably.

The vote of thanks was carried with acclamation and was acknowledged by the Author.



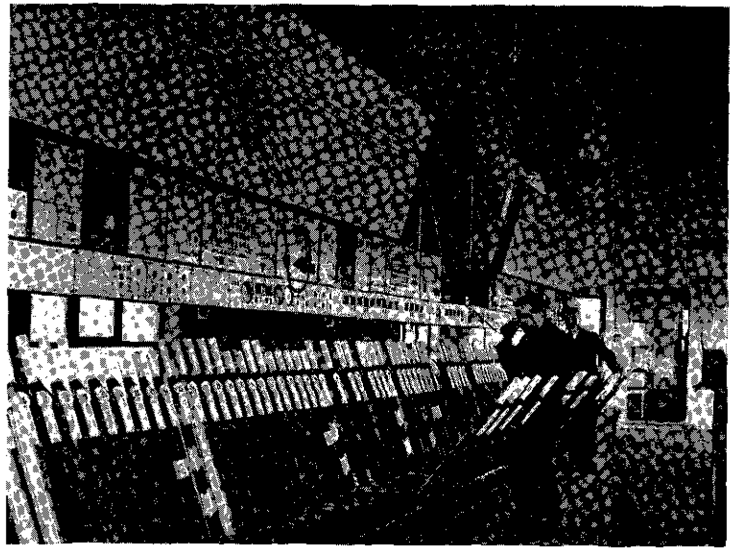
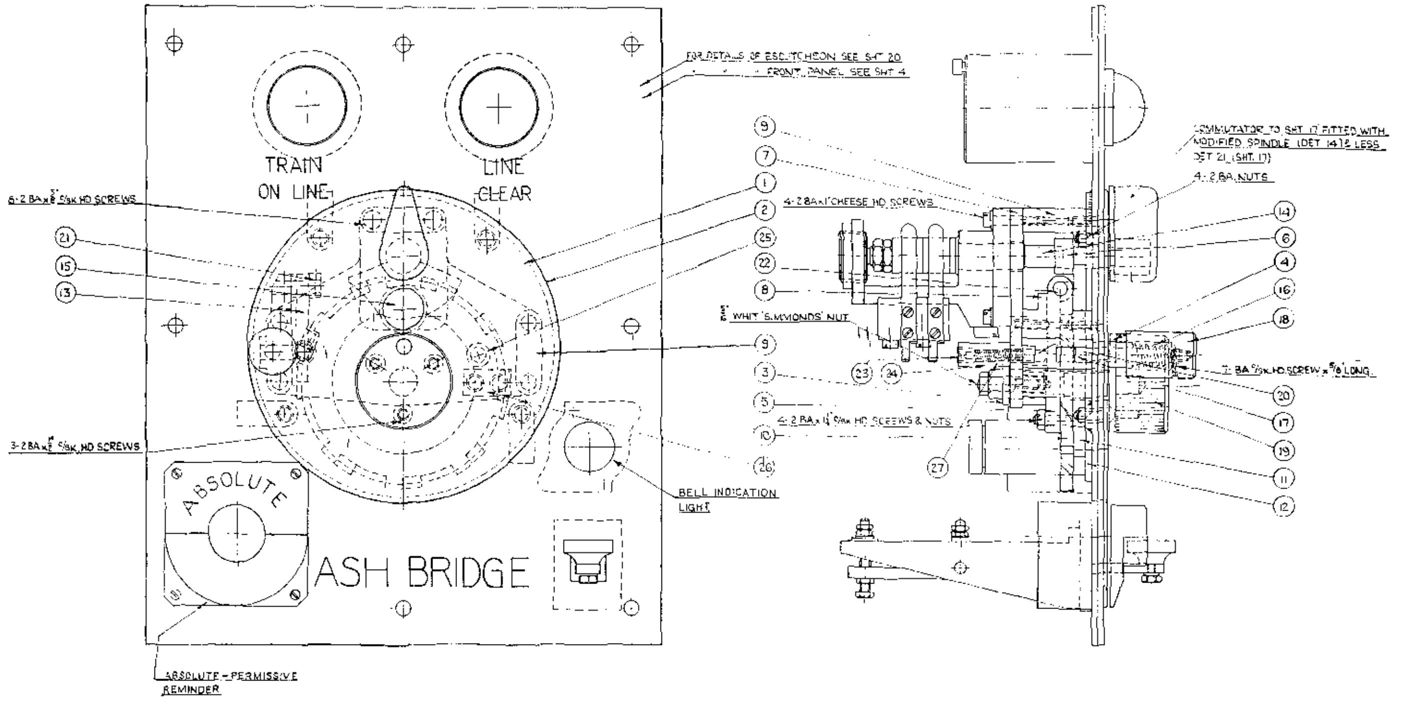


FIG. 15



HEATON NORRIS JUNCTION SIGNAL BOX
INSTRUMENT SHELF
'LUMINOUS' PERMISSIVE BLOCK COMMUTATOR MOVEMENT
SCALE – ⅓RD SIZE

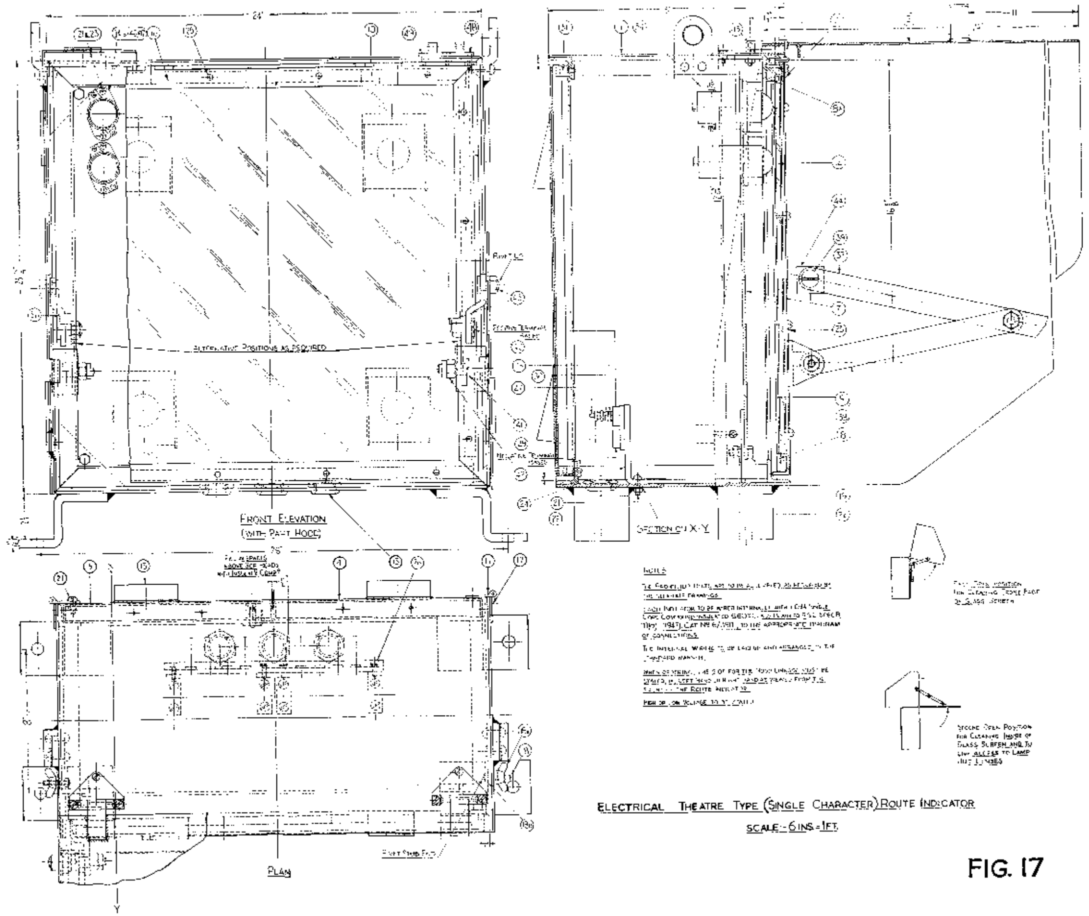

FRONT ELEVATION
(WITH PART HOOD)
SECTION ON X-Y
PLAN
ELECTRICAL THEATRE TYPE (SINGLE CHARACTER) ROUTE INDICATOR
SCALE:- 6 INS = 1FT.

FIG. 17

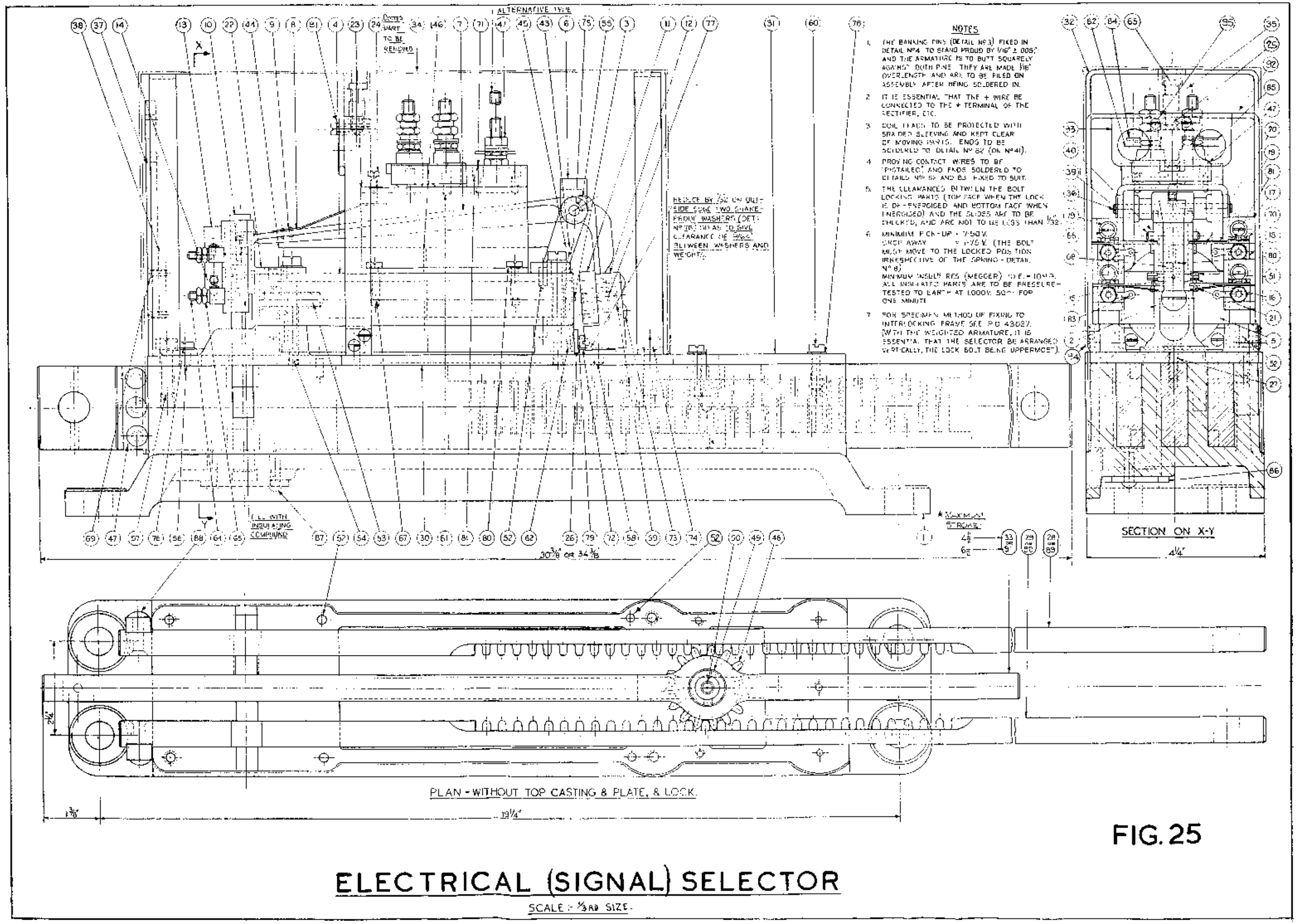

NOTES
PLAN - WITHOUT TOP CASTING & PLATE, & LOCK.
SECTION ON X-Y
ELECTRICAL (SIGNAL) SELECTOR
SCALE:- ⅔RD SIZE.

FIG. 25

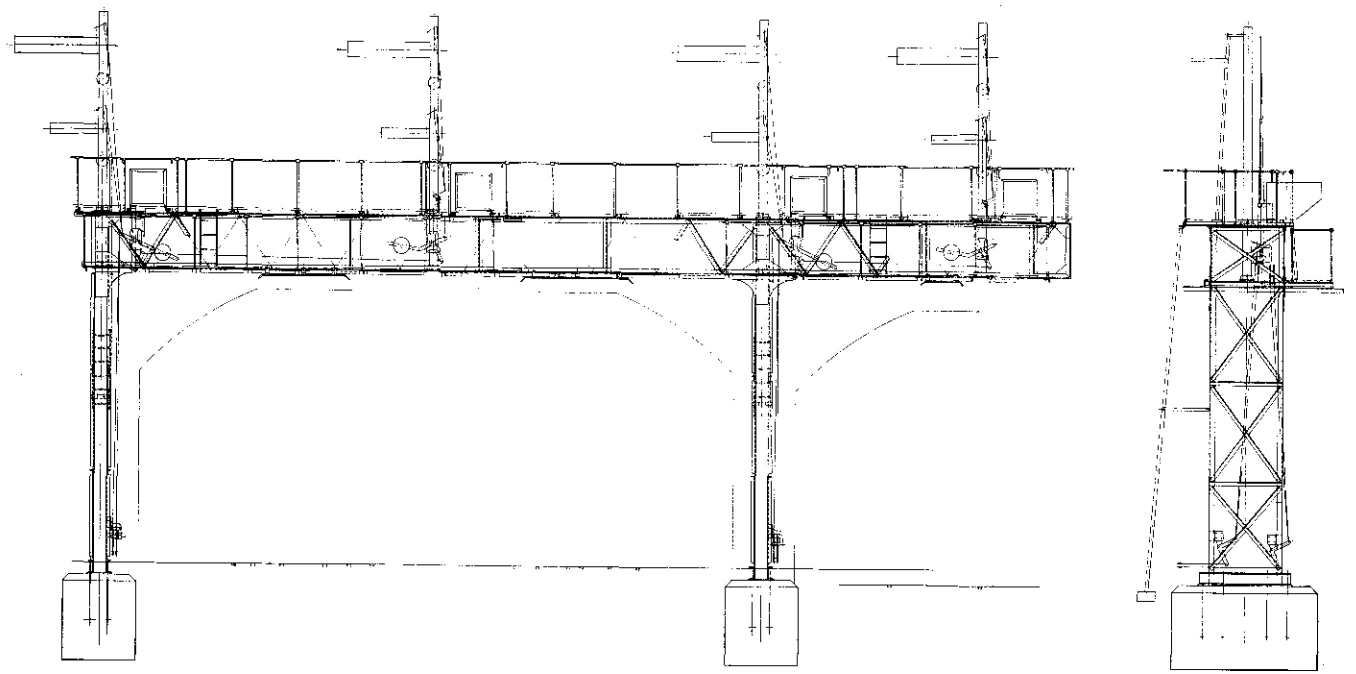
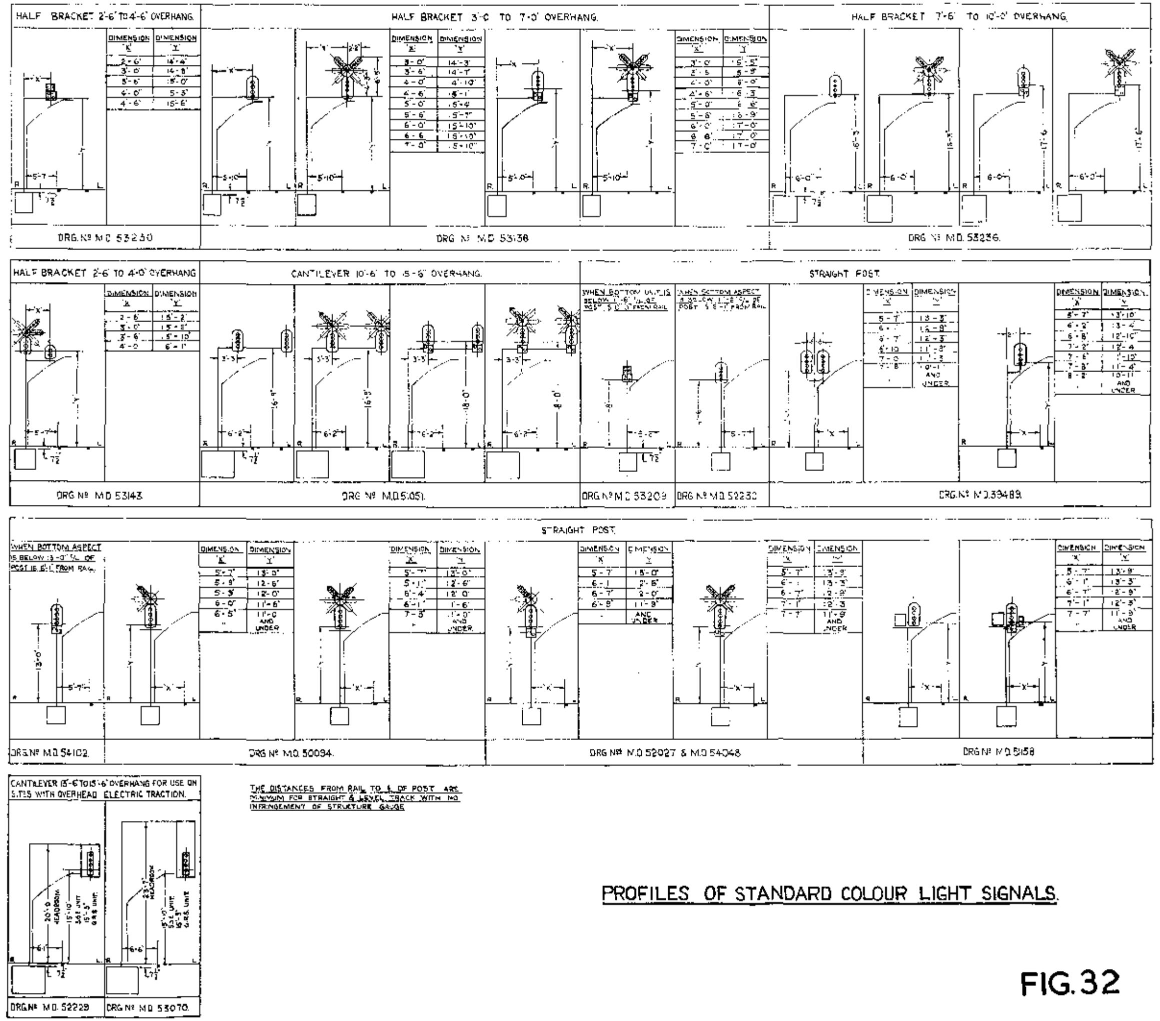


FIG. 31

SEMAPHORE GANTRY.
ALL WELDED, WARREN-BRACED CONSTRUCTION.



PROFILES OF STANDARD COLOUR LIGHT SIGNALS.

FIG. 32

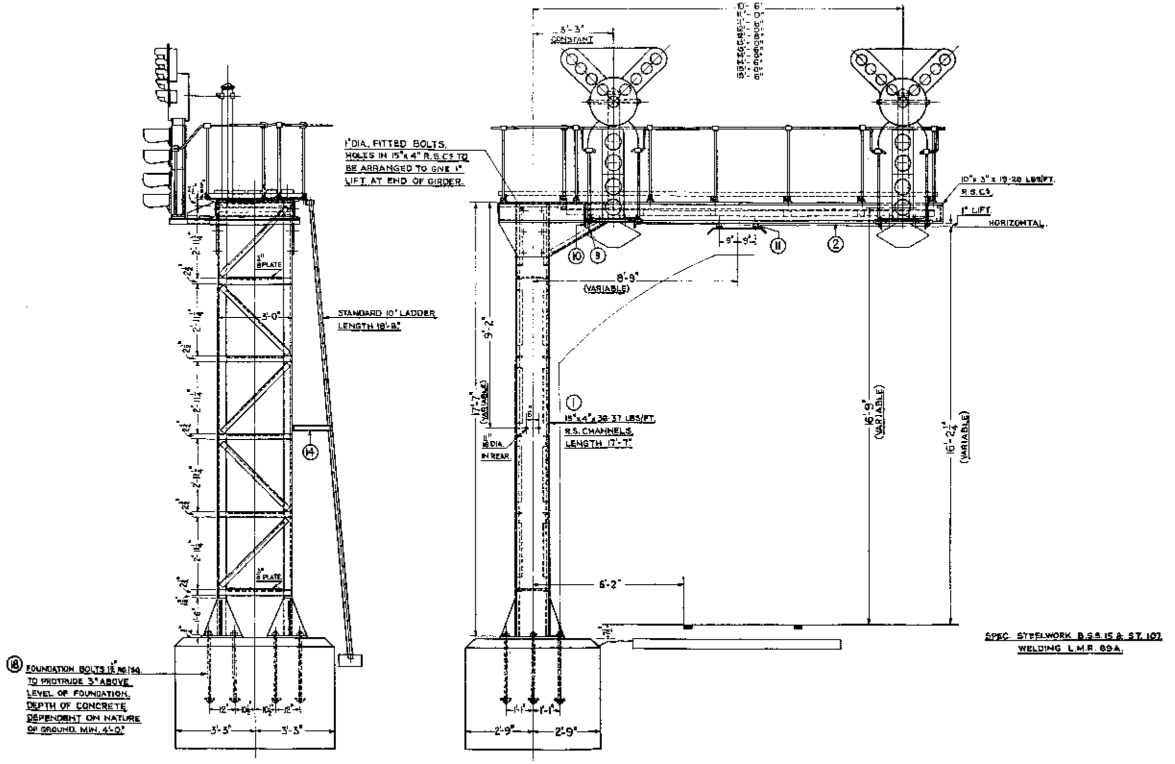


FIG. 33

STANDARD COLOUR LIGHT CANTILEVER SIGNAL WITH DIRECTION INDICATOR.

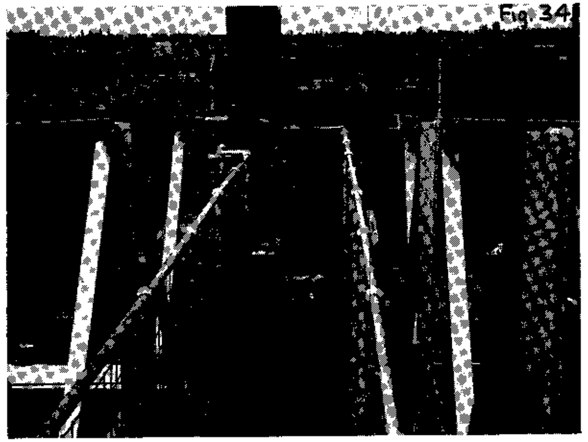


Fig. 34

Fig. 35

FIG. 36

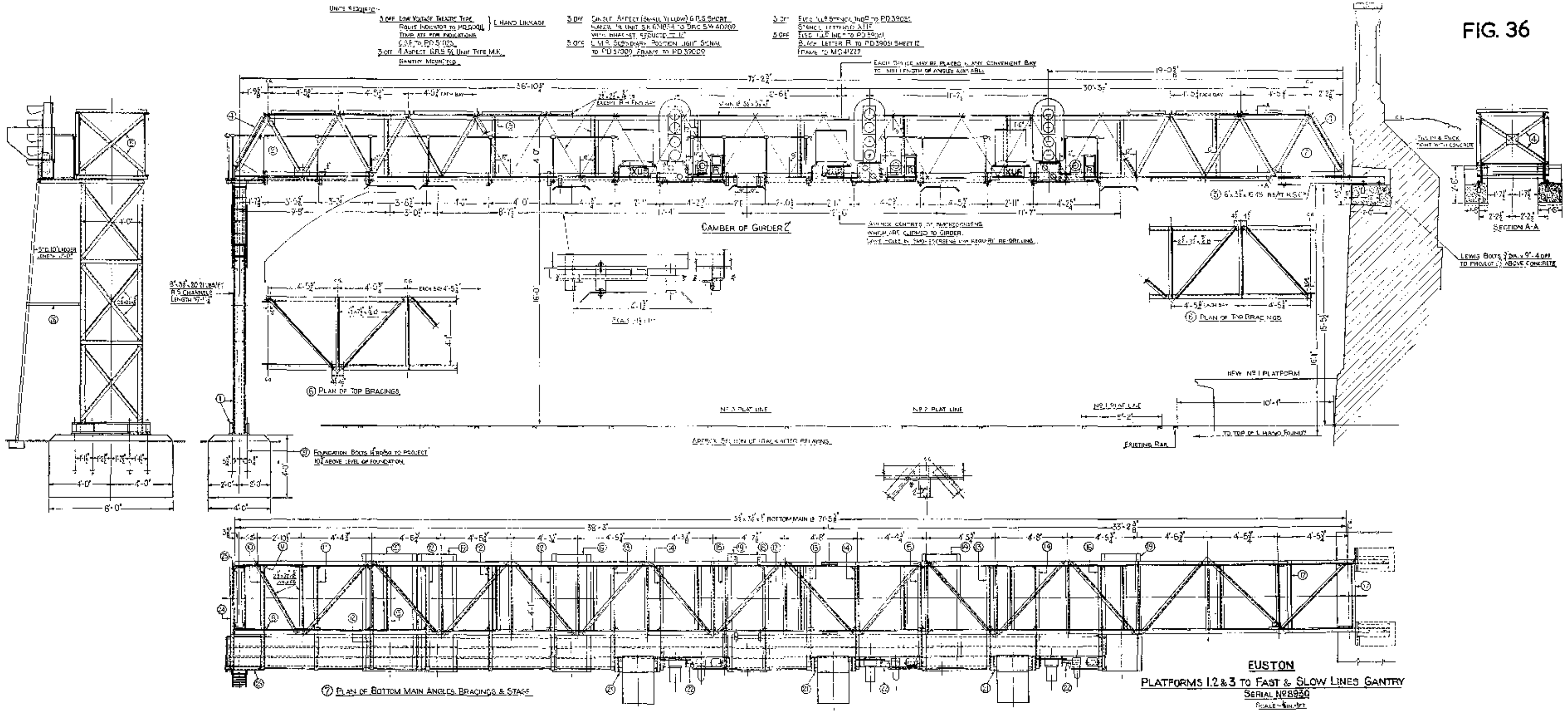
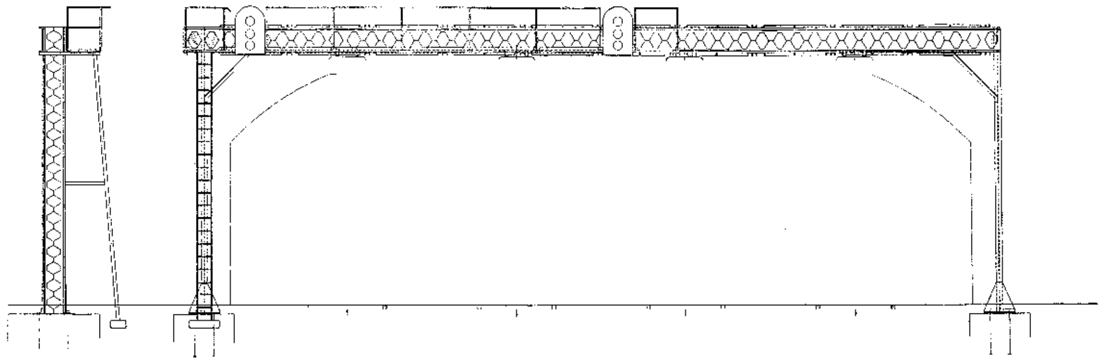

EUSTON
PLATFORMS 1.2 & 3 TO FAST & SLOW LINES GANTRY
SERIAL No 8930

FIG. 37



COLOUR LIGHT SIGNAL GANTRY SPANNING FOUR TRACKS
WITH 'CASTELLA' GIRDER AND STANCHIONS

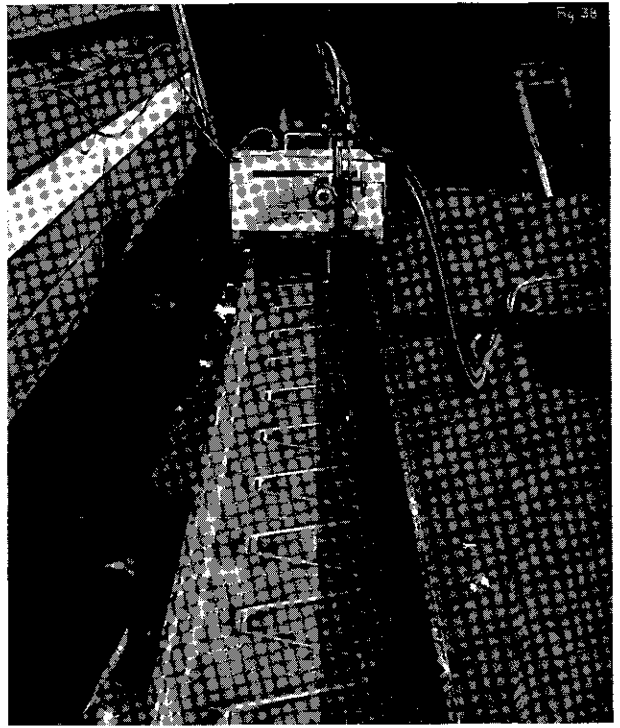


Fig. 38

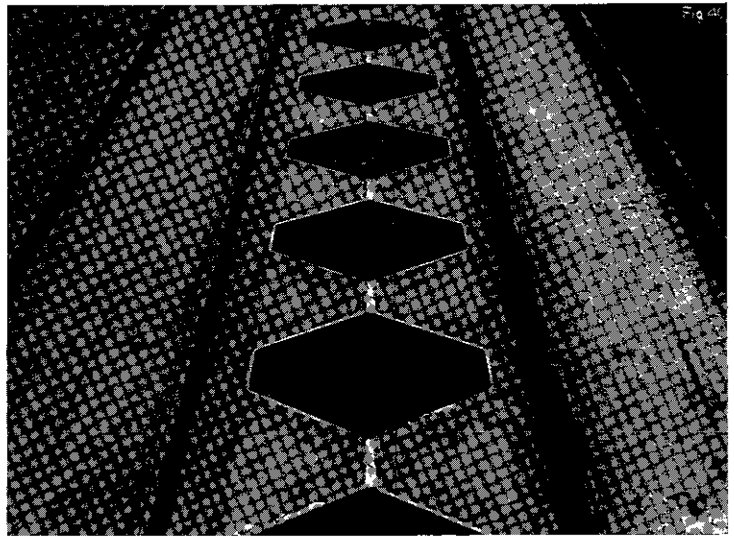


Fig. 40

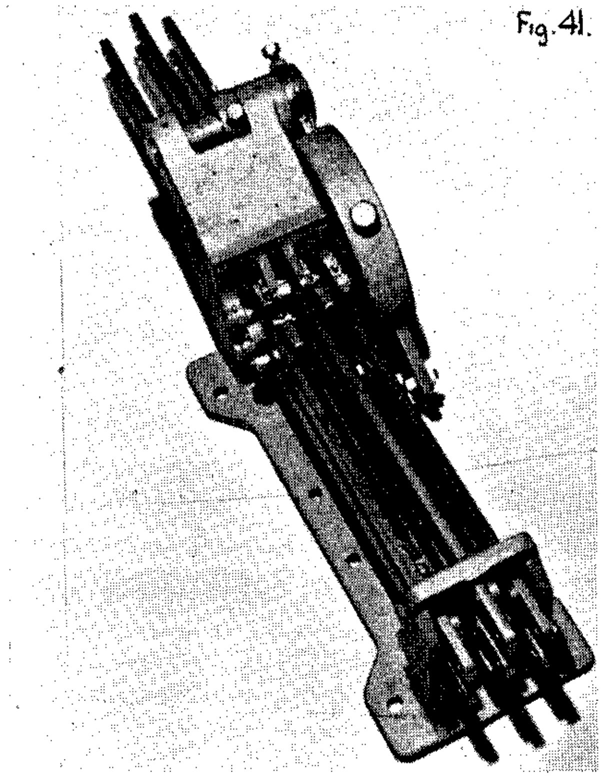


Fig. 41.

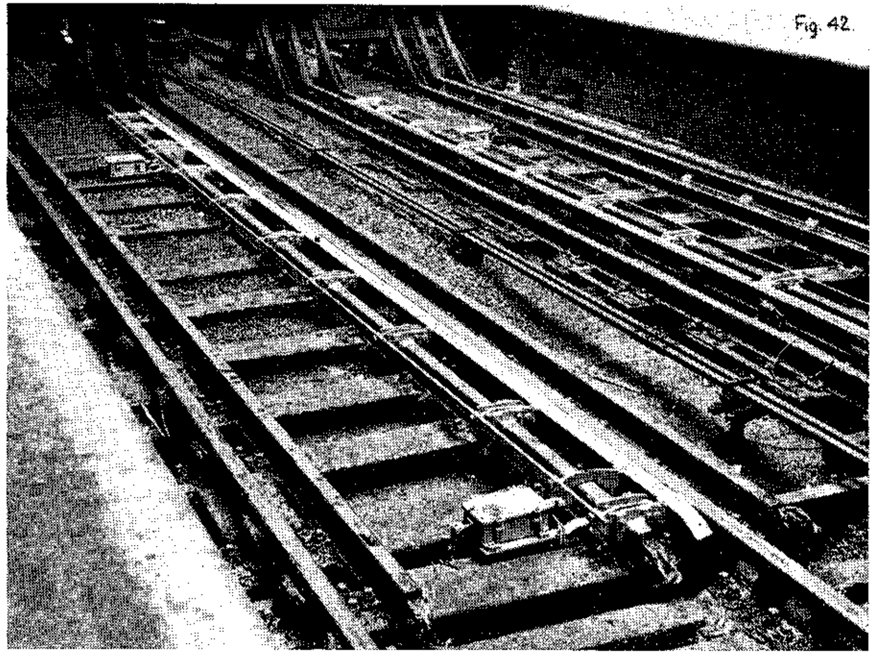


Fig. 42.

FIG. 43

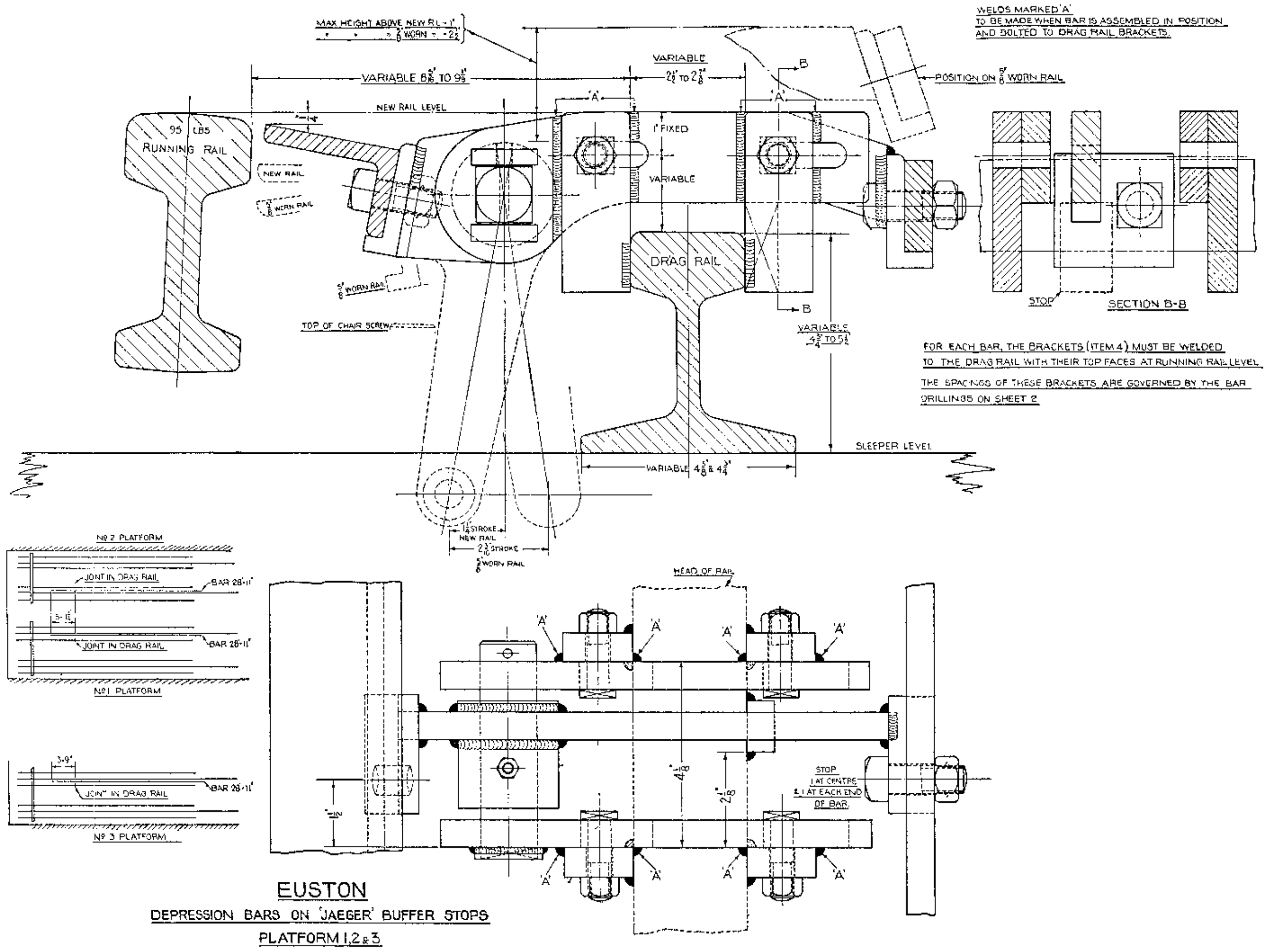


Fig. 44