concluding
ELECTROMAGNETS
by John Langan

Electromagnets for Pulling

So far we have considered the use of a coil to create a magnetic field from one pole above the track to attract the armature on the coupling wire downwards and so disengage the coupling. When we come to make use of the electromagnet as a means of actually physically pulling, as opposed to its usual role of simply moving over contacts, we have to adapt the coil in a different way.

One method which is used for operating signals and points is to allow the iron core of the electromagnet to float. In this way we obtain good movement of the core, but unfortunately it generally requires a relatively heavy current consumption to produce a strong pull. Many commercial point motors are based upon this system possibly to keep down the coil size and, of course, the cost. In this connection it is important to repeat that the current supply to such ancillary equipment shall be separated from that supplied to the track through the controller, otherwise the running of a train will be greatly affected when you switch your pointwork on and off. Admittedly these heavy currents are only on momentarily to create the movement, but very often extra devices are also required, such as clips, for locking a point after changing. I prefer to use the electromagnet, based on the principle of the relay which when using a small current, will change a point over and hold it in position. A simple return spring holds the point in the normal running position, when the current is off. This is achieved by extending one pole of the iron core and bringing it forward by means of a yoke or frame to be in line with the opposite pole as shown in Fig. 15. A moving armature across the poles then completes the magnetic circuit. This is the principle used on electrical relays for many years, and a popular one used by modellers has been the Post Office 3000 type relay as shown in Fig. 16. By attaching an arm to the swinging armature of such a relay the movement can be magnified to suit your requirements. The contact changes on the relay are also useful when a change in the electric circuit is required as the relay is operated.

One of the problems in designing an electromagnet to pull over a signal arm or a point, is to determine just how much pull we require. Some idea of this force can be obtained by hanging small known weights (such as from the kitchen scales) to a suitable place until the mechanism is actuated. To then design an electromagnet to give this pull is another matter, since so many variables are involved in its construction. To overcome this problem I decided to test some of my coils in order to determine the pull of the electromagnet against the current taken. Actually on these tests I used my voltmeter because this had a greater deflection than my ammeter, and therefore more readable, and divided the figures obtained by the known resistance of the coil to obtain the amperes value. Having the amperes value and knowing the number of turns of wire on the coil I was able to calculate the 'Ampere-Turns' value for each loading and so make up a graph of the pull in ounces against the 'A.T.' value as shown in Fig. 18. These tests were carried out by using the skeleton frame from a 3000 type relay and applying weights to the armature frame as shown in Fig. 17, and noting the volts taken. I do not claim that the results as shown in the graphs of Fig. 18, are of laboratory accuracy, or of some new scientific wonder, but I do find them a good guide from which to start the design details of the coil. Naturally the results shown only apply to coils contained in a yoke as shown, and with 1mm (0.04in.) air gap at the armature as shown in Fig. 17. As the armature closes, and the air gap reduces, the pull increases rapidly. I make small coils with a ¼in. dia. core and use a ⅜in. dia. core for larger sizes. It will be seen that the larger coils have a better performance when using the ⅜ins. dia. core. It is important to note that the sectional area of the yoke should be at least equal to the cross sectional area of the core used, to allow the free flow of the magnetic field.

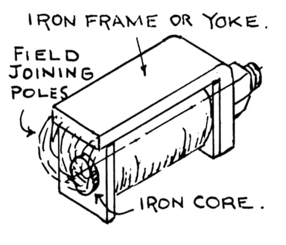

FIG. 15. BRINGING THE MAGNET POLES TOGETHER

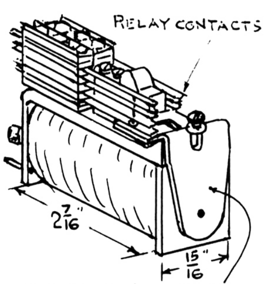

FIG. 16. POST OFFICE 3000 TYPE RELAY.

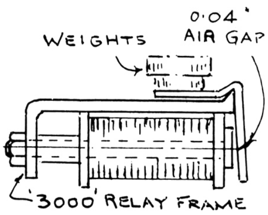

FIG. 17. TEST RIG FOR PULLING POWER

Signals

The electromagnet I made for signal operation is shown in Fig. 19. The core is a ¼in. diameter bolt having a cross sectional area of 0.049 sq. in., and so I made the frame from ½in. × ⅛in. steel bar. The armature is from 1/16in. steel plate and bent to shape as shown, being retained by an 8BA brass screw and also a brass spring. An 8BA brass screw is also fixed into the face of the armature and slightly projects so that it prevents actual contact between the armature and the face of the core. Alternatively, of course, a brass rivet could be used, otherwise residual magnetism would hold the armature for some time after switching off the current. Soldered to the armature face is a piece of OO rail, drilled to receive the wire to pull the signal and also to hold the return spring. The length of the OO rail arm magnifies the limited movement at the armature, so that with only 0.04in. movement at the armature the travel at the signal should be adequate. The construction of the coil is the same as described for the Alan Jackson uncoupler, but the core should be machined or filed to have quite a large face as shown in Fig. 19.

Designing the Coil

In the smaller scales a pull at the armature of half ounce would appear suitable, but allowing for the pull of the return spring we will aim for at least a pull of 1 ounce. From the graph I have therefore decided to design for an 'Ampere-turns' value of 150, and so proceeding as before we first obtain the amount of resistance per turn of wire required, therefore:

$$= \frac{\text{Volts}}{\text{AT}} = \frac{12}{150} = 0.08 \text{ ohms per turn}$$

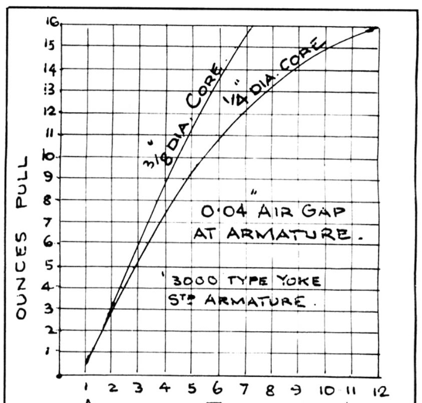

FIG. 18, GUIDE FOR COIL DESIGN

Having an old coil of 41g wire available, reference to table Fig. 4. gives me 0.6307 yards of wire per ohm resistance, and so the coil mean diameter would be by formula:

$$\frac{0.08 \times 0.6307 \times 36}{\pi} = 0.578\text{in.}$$

which is a reasonable size to work on. The core size will be 0.266in. ($^{17}/_{64}$in.) as before, and together with the above mean diameter of 0.578in. produces a calculated outside diameter for the coil of 0.775in. Sideplates were made to suit at $^{13}/_{16}$in. square. Alternatively, the core size could be based upon a 7mm dia. drill (0.276in.) if this was more convenient.

From these figures the depth of wire space ('T' in Fig. 5.) equalled 0.254in. which with the enamelled wire measuring 0.005in. dia. gave approximately 50 wires deep. Referring to table Fig. 4, the current allowable for a 41g wire at a rating of 2000 amps per sq. in. would be 0.03 amps. I decided to obtain the 150 AT value by using 6000 turns of wire with a current consumption of 0.025 amperes. With the depth of wires of 50 as above, and 6000 turns, the coil length in wires will be:

$$\frac{6000}{50} = 120$$

And so the actual length of the coil will be 120×0.005in.=0.6in. which when allowing the 10 per cent for winding the former gives 0.66in. long.

I agree that this does not give as good a proportion of diameter to length as an electromagnet, but I did not have any finer wire available which would have made the diameter smaller. The total resistance of the coil is

$$\frac{12 \text{ volts}}{0.025 \text{ amps}} = 480 \text{ ohms}$$

corresponding of course with 6000×0.08=480 ohms. A quick check now on the cooling of the coil:— Surface area=$\pi \times 0.775 \times 0.66 = 1.69$ sq. ins. Allowable current

$$= \frac{\sqrt{1.69 \times 0.2}}{480} = \sqrt{.00075} = 0.027 \text{ amps}$$

So we could expect the coil to keep reasonably cool if left on for some time. On test I made a rough mock-up of a 7mm scale signal, to exaggerate the loading, and the electromagnet operated very satisfactorily, so there would be no problem on smaller scales.

Pointwork using Relay Coils

The pull required to operate pointwork varies considerably depending upon the type of point construction used. My 4mm scale scratch built points based on the prototype operation require quite a pull of about 3 ounces, which when multiplied by the leverage required to obtain sufficient movement at the point from the small movement at the armature, amounts to about 9 ounces pull from the electromagnet. This means quite a large coil and plenty of wire if the current is to be kept to a low consumption. A test on a P.O. 3000 type relay of 200 ohms resistance gave a pull of 8 ounces when given 12 volts.

For many years we have used this type of relay for point operation and the general set up is shown in Fig. 21. A 3000 type relay has the armature movement magnified about 3 to 1 by fastening to it a length of ⅛in. square brass bar. This movement is then transmitted to the moving sleeper by a 2 to 1 lever under the baseboard. The change over contacts on the relay change the polarity of the track current supplied to the 'frog' of the point, to allow '2 rail' electrification.

Making big electromagnets such as this is not an easy proposition in the home workshop. The amount of wire required can be quite expensive and the winding by hand very tedious. The more serious problem is, however, the making of a suitable frame or yoke. With the ⅜in. dia. core, the yoke section is a minimum of $^{11}/_{16}$in. × $^{5}/_{32}$in. thick, and this is quite a heavy section to bend in the ordinary vice at home. One idea I tried was to divide the section of the material to form two poles to meet the central core as in Fig. 20. This makes the yoke more workable for bending, but the design has disadvantages in that the three poles must line up equally for full power and the small armature movement has to be magnified by an external lever which often entails a chance of lost motion. So if you can possibly obtain some ex-P.O. 3000 relays from the electrical surplus dealer this is a better proposition for this item.

Coil Calculation

However if you have a broken coil and wish to rewind, then the procedure would be as already described. Should you wish to obtain a coil with different characteristics I present the following example based on the formulae already given. For instance, if we wished to have a pull of 9 ounces at the armature the graph shows the AT value to be approximately 400. As a number of points may be 'on' at any one time we require to keep the current consumption down so let us say 10,000 turns of wire at 0.04 amps to obtain our 400 A.T. The resistance per turn

$$= \frac{12}{400} = 0.03 \text{ ohms}$$

Using 37g wire the current consumption for a rating of 1000 amps per sq in. equals 0.036 amps. Mean coil diameter

$$= \frac{0.04 \times 1.506 \times 36}{\pi} = .692\text{in.}$$

Calculated outside diameter=0.9in.
Depth of wires, 'T' Fig. 5

$$= \frac{0.9 - 0.38}{2} = 0.26\text{in.}$$

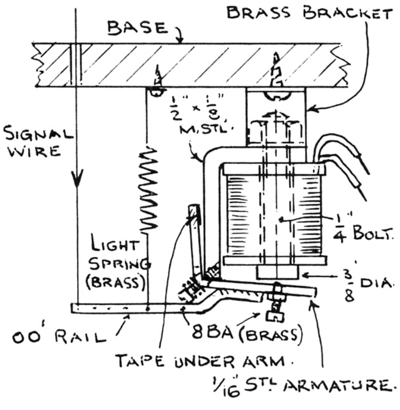

FIG 19 ELECTROMAGNET FOR SIGNALS.

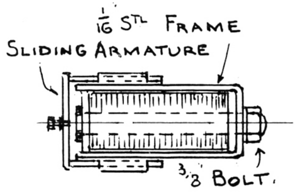

FIG. 20. EXPERIMENT FOR ELECTROMAGNET WITH LIGHT FRAME.

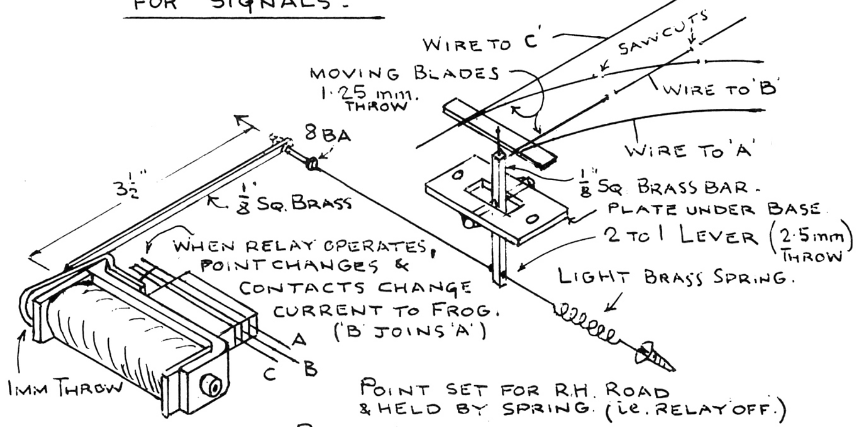

FIG 21. POINT OPERATION BY '3000' TYPE RELAY.