HIGH EFFICIENCY LOCO DRIVES

BY SIDNEY STUBBS

Older readers may recall the pioneering work in 2 rail, EM gauge carried out by Alex Jackson, BSc, of Jackson coupling fame, in the immediate post war years until his premature death in the early fifties. He had already become legendary in Manchester modelling circles by virtue of his 119 volt AC outdoor 1 gauge line using locos fitted with Hoover motors and 10lb flywheels. Anybody handling one of those for the first time suddenly discovered what driving meant when faced with a station and dead-end buffer stops.

In 1948, he moved over to EM and applied the same basic ideas to this new gauge. Briefly, the main principles were:

1. 24 volt motors instead of 12 for better collection and lower current
2. Many more turns of finer wire on the armature than was then the practice since power depends on ampere-turns
3. The smallest possible commutator diameter and lightest possible brush pressure to reduce adverse frictional torque and, thus, power loss, to an absolute minimum
4. Close fitted phosphor bronze sleeve shaft bearings to reduce, or obviate 'chatter' and thus promote a quiet motor
5. The heaviest possible, lead rimmed flywheel, accurately machined all over for perfect balance
6. The smallest possible diameter of work with proper ball thrust bearings at each end to relieve the armature shaft of thrust load
7. Split axles with the centres insulated from the ends, current being collected via the wheels, bearings and insulated frames as per figure 1.

A group of Manchester modellers adopted these principles and have preserved them down to the present day. Many older modellers will recall the high standard of running on John Langan's 'Presson' layout which appeared twice at the MRC London show and on many occasions at the MMRS Manchester show.

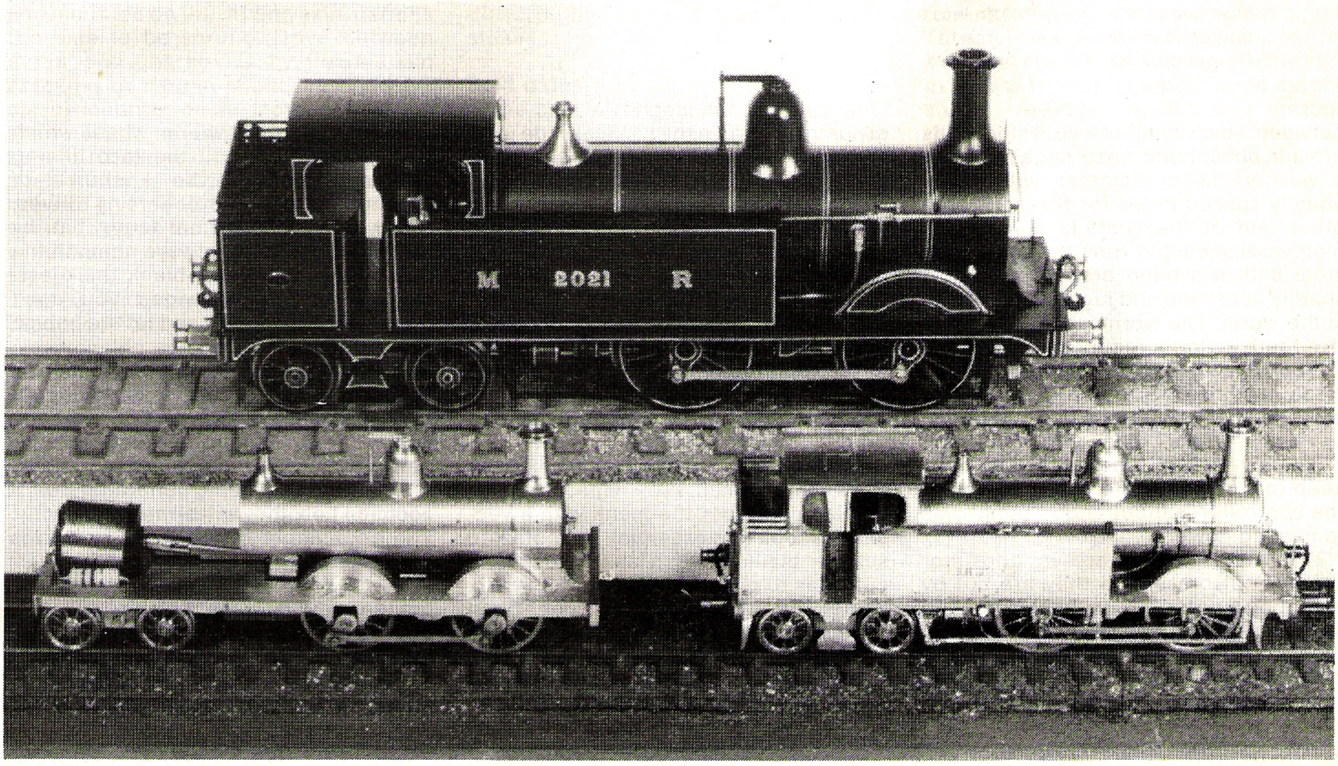
For many years, attainment of these ideals involved making one's own motors from scratch and also making one's own worm gears, split axles and chassis since nothing of sufficient standard was available commercially. However, the advent of the so-called 'can' motors such as Sagami and Portescap has provided a much better commercial article. In particular, the Portescap motors 1616 and 1624 have commutators only 3/64in in diameter, sintered bronze bearings and a very efficient magnetic field arrangement giving rise to high power with low current consumption, excellent low speed operation and a very low noise level, all contained in a package much smaller than anything hitherto available for 4mm scale use.

It was the latter consideration which attracted me towards their use in 'EM' Midland Railway Johnson and Kirtley 0-4-4 tank locos which presented quite a problem in devising a small enough purpose built motor and accommodating it and a flywheel and gear unit so as not to be visible within the outlines of these engines. A request that I build an 'O' gauge version of the Johnson determined me to build all three together and to try one of the 1624 motors in the 'O' gauge engine too. I did not, however, employ the four-stage bevel/spur Kean-Maygib version, excellent piece of work that it is, because it would not fit the two EM locos, it cannot have a flywheel, and I find the gear whine quite unacceptable. In my opinion, only a worm gear can give a quiet drive and spur gears, if used at all, should follow the worm drive at the low speed end.

Worm gear units

Many years ago, I developed an oil bath totally enclosed worm gear unit for 4mm scale. It employs a thread form to the old BSS 978, 'Gears for Clockwork Mechanisms', having an involute tooth form with a 20° pressure angle. The worm is 1/8in outside diameter on a 1mm shaft and it is screwcut on the lathe, twenty-eight threads per inch, two start, which gives a helix angle of 12°34'. There is a ball thrust bearing at the input end of the box made up of two hardened silver steel washers

The three locos. The Kirtley is incomplete but this shows how the 1616 motor fits into the bunker



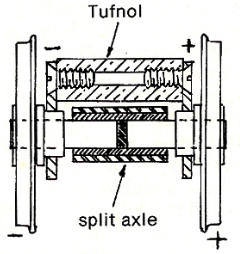


Fig 1

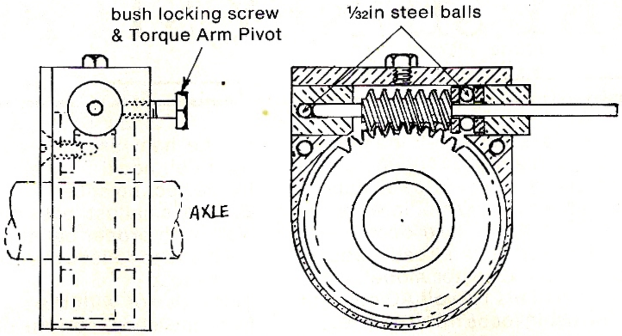


Fig 2

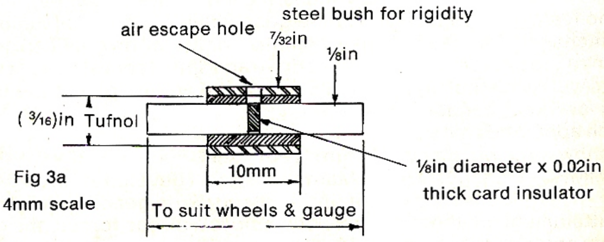


Fig 3a
4mm scale

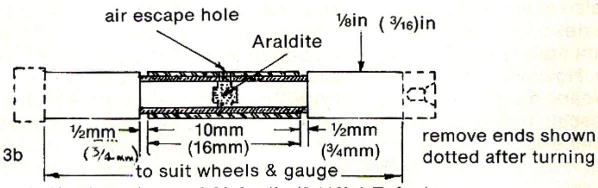


Fig 3b

half-axle stubs are 0.067in dia (0.116in) Tufnol bush is 0.102in dia (0.157in) bores of Tufnol bush & steel sleeve are 0.001in less than these figures to provide a good force fit ('O' gauge dimensions in brackets)

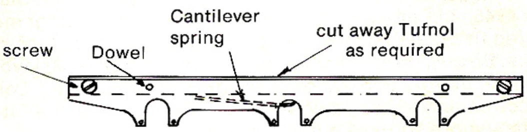
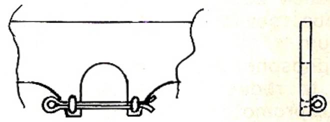


Fig 4



detail of 1/32 split pin horn keep

between which run three 1/32in steel balls in a thin phosphor bronze 'cage', actually a washer .130in diameter with three equally spaced holes for the balls. The other end of the shaft is domed and highly polished and runs against a 1/32in steel ball in a blind bronze bush. The shaft is hardened and highly polished as is the worm. The worm wheel has forty-five teeth giving a reduction of 22½:1.

Ideally it should be higher but this would lead to a worm wheel and casing so large as to prohibit its use in medium or small wheel locos. With a high efficiency motor, one can, in any case keep to a decent scale speed by use of the controller without undue penalty as to hauling power.

The worm wheels are in phosphor bronze, not brass, and they are cut by mounting a fluted tap, or 'hob', cut to the same thread form as the worm itself, in the lathe chuck to run dead true and mounting up the worm wheel blank to run free on a suitable spindle held in the dividing head or in the vertical slide vice. The worm wheel blank is then advanced to the hob, which engages it and drives it round, just as the worm and wheel in the loco but, since the hob is hardened and has cutting flutes, it cuts accurately formed teeth in the worm wheel, a process known as 'hobbing'. The only important point is that you MUST, first, cut a series of 'gashes' in the blank equal to the required number of teeth but not quite so wide or deep as the final tooth space. Otherwise, the hob cannot start to drive.

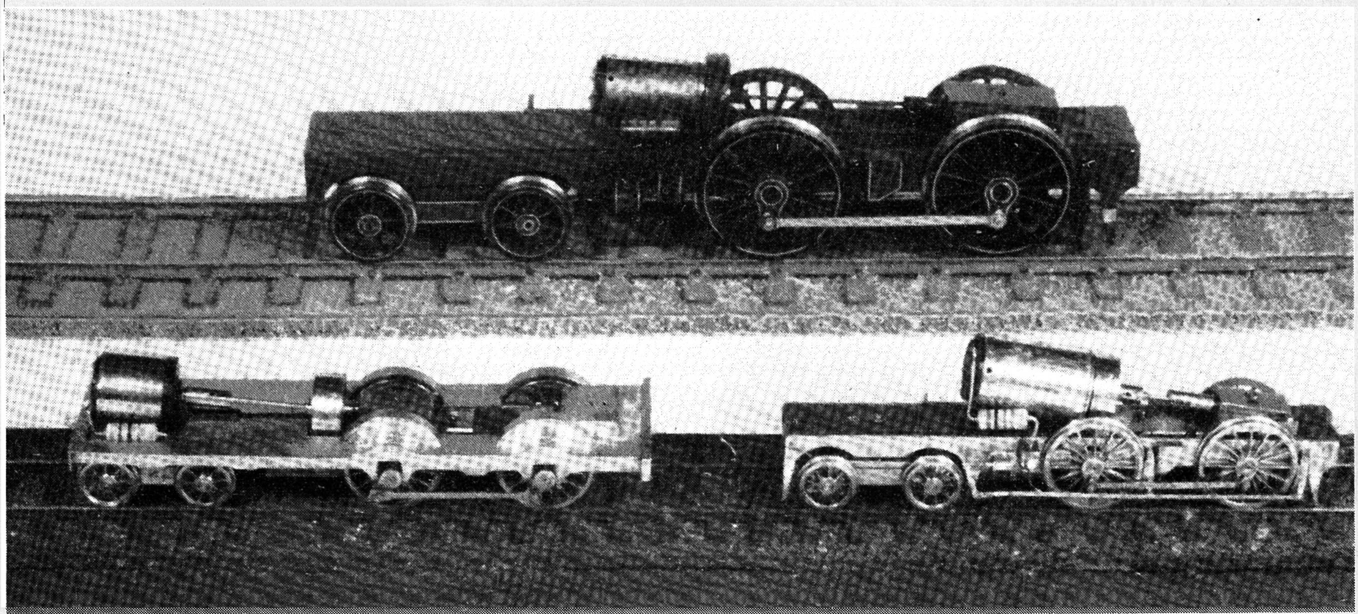
These gashes can be cut in the dividing head using a small, vee-shaped cutter or by planing across the blank with a vee-shaped tool. It is essential, of course, to set the blank at such an angle to the cutter as to give the correct tooth helix angle. All the foregoing has been covered more fully in books on the lathe or in the pages of the *'Model Engineer'*.

Merely sinking the hob into the blank produces the familiar radiused or 'throated' teeth on the worm wheel which restricts side play on the loco driving axle and tends to be a source of unwanted friction in our tiny drives. Accordingly, I cut the teeth flat by feeding the blank sideways beneath the hob by the amount of blank thickness. This works well provided you don't overdo the movement and let the hob go out of engagement.

Incidentally, by setting the blank so that its axis differs from a right angle to the hob axis by the amount of hob helix angle, one can cut ordinary straight spur gears of any desired number of teeth by this method and, being generated from a common hob, they will all mate perfectly. The helix angle of the worm or hob is calculated from the formula

$$\text{tangent helix angle} = \frac{\text{pitch of thread}}{\text{pitch diameter} \times \pi}$$

NB. for a two start worm, the pitch, or



'lead', is twice the pitch of each thread, eg. in the case of a ⅛in diameter worm, 2 start, 0.102in pitch diameter, 28 threads per inch (0.03571in pitch)

tangent helix angle =
0.03571in x 2
0.102in x 3.1416
= 0.2229

and helix angle = 12°34'

The result of all this is a worm gearbox in which the drive is reversible ie one can turn the driving wheels by hand. The gearbox, being separate from the motor and mounted on the driving axle, permits the axle to be sprung. Drive between motor and gearbox is by flexible pin coupling or cardan shaft. The flywheel can be mounted on the motor or gearbox shaft, or in its own bearings with a separate flexible drive if a double ended shaft motor is employed. The gearbox needs a pivoted torque arm, anchored to some point on the chassis, to prevent it winding its way round the axle under load.

An 'O' gauge variation of the box was produced for the 'O' gauge loco to the same design scaled up. The worm has sixteen threads per inch and 1mm diameter steel balls (ex ball point pens) were used. Figure 2 shows the details of the 4mm box.

Flywheels

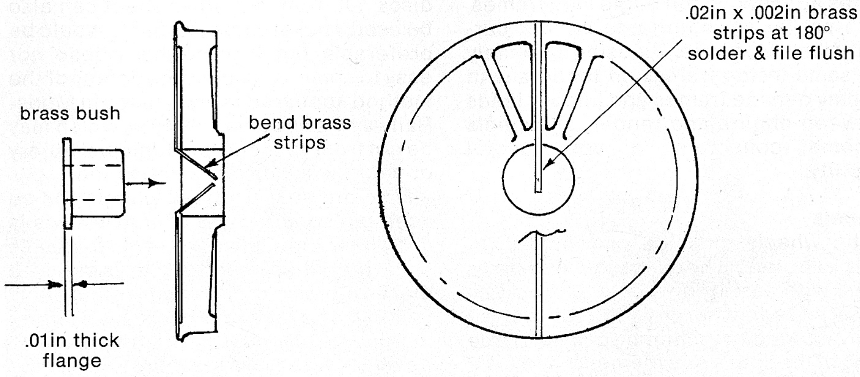
For the older type of motor which does not run so freely as the Portescap, heavy flywheels with lead rims up to 1in diameter are usual but the Portescap is so light and free running that plain brass flywheels, ⅝in diameter by ¼in thick have proved sufficient. Two identical grub-screws at 180° are employed to preserve balance. Since there was much more space in the 'O' gauge version, a 1in diameter flywheel was fitted. This loco can freewheel eight feet after the current is cut off; the EM ones manage about four feet. They will all start and run at so low a crawl that one can see each coupling of the train take up. This is achieved with an ordinary resistance controller or a simple emitter-follower transistor controller. Pulse type controllers are useless where a flywheel is used and many, by their principle of operation, set up a pulsed 'rattle' from the motor at low speeds, reminiscent of a clapped out tractor on its way to the breaker; okay for diesel outline models but quite wrong for steam.

Split axles

The best, strongest and simplest split axle is that shown in figures 1 and 3a. However, these do require axleboxes in hornguides since one cannot push the axle through frames with fixed bushes or holes.

Also, the Kean-Maygib gearbox will not take an axle with a centre larger than ⅛in diameter. In consequence, a design of split axle as at Figure 3b has been developed for such cases. It is, however, far more demanding in time (and cost) to make. The centre steel bush and stub axles are made from free-cutting mild steel a few thou larger than the finished axle and one of the stub axles has a centre in its outer end. The insulating bush forced in the outer steel bush is turned from 3/16in diameter 'Carp' brand Tufnol and, on assembly, a spot of Araldite is put in the bore before the stub axles are forced home. Trapped air and surplus Araldite are expelled through the small hole in the centre bush. The inner ends of the stub axles have a

Fig 5

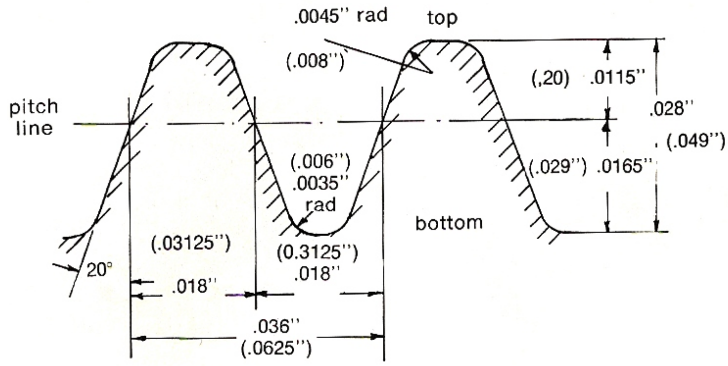


fine bore bush after fitting boring from back to avoid risk of pushing out.
Press only on centre bush when fitting to axle

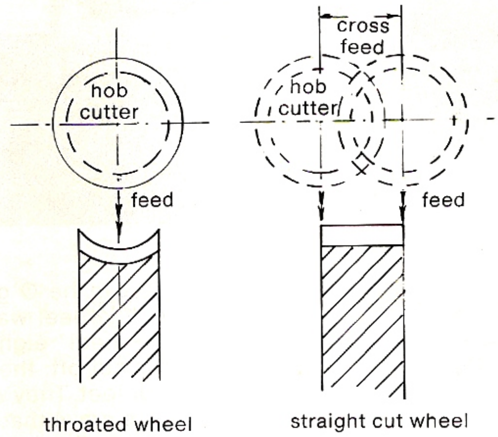
shallow slot cut across to provide, with the set Araldite, a key against turning in service.

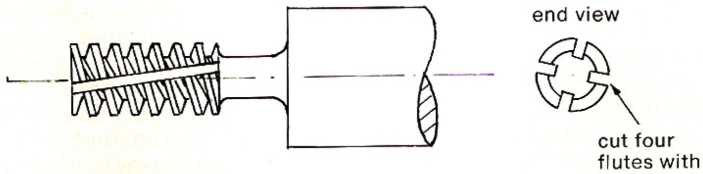
After curing the adhesive, the axles are held in the lathe collet, supported by the back centre and turned parallel to size. The excess at each end is then parted off. The O gauge axles have been successfully squared and tapped for Allen screws or threaded to take screwed tender and bogie wheels.

The use of split axles obviates the need for collectors on the backs of wheels. Some of the collector plungers fitted today, especially in 4mm scale bear so heavily that all benefit of the flywheel is lost and slow running is quite impossible, other than by 'pulse' control which is not recommended by the Portescap firm.



thread for (O gauge sizes in brackets)





Hob – silver steel hardened & tempered. For strength, the diameter can be greater than that of the worm. This alters the helix angle and the blank & cutter axes (normally at 90°) will required adjusting by the difference

Chassis

General details are shown in figures 1 and 4. I usually use a length of Carp brand Tufnol, milled to width as a frame spacer. The sideframes, cut as a pair, are then screwed and dowelled each side with their top edges set about ten thou below the top of the Tufnol to prevent shorts by contact with the loco footplate. The Tufnol is then cut away where the gearbox, motor, inside motion etc are to be sited.

The axle holes are drilled using the previously made coupling rods as a jig and then opening out to 3⁄16in (4mm) or 5⁄16in (7mm). The metal is then cut away below the hole to form horn guides. A 1⁄32in brass split pin is put through the frame at the bottom of each horn cheek, soldered and filed flat on the outside of the frame, the eye being inside. A long 1⁄32in steel split pin, passed through these eyes retains the bearing bush. The latter is a flanged bush with the flange outside the frame. A spring steel wire of about 28 gauge (EM) or 20 s gauge (7mm) is soldered at its end inside the frame to act as a cantilever spring on the protruding end of the bearing bush. Bogies use the same construction, and cantilever springs, soldered inside the main frames and bearing on rubbing plates attached to the bogie side frames, both confer springing and collect current from the bogie. By using precisely the same inside frames on tenders with dummy outside frames and jumper leads between engine and tender, all wheels become collectors, a very useful amenity.

Wheels

The wheels must be conductors for split axle use. The O gauge engine is fitted with cast iron wheels supplied by Messrs Wednesbury Wheels of Walsall who also kindly machined squares on the ends of the split axles for me. The two EM engines have brass wheels cut from the solid and nickel plated. This means quite simply that blank wheels are turned up, the spokes, balance weight and crank are marked out on each wheel and they are then cut out with a fretsaw and finished with fine needle files. Usually the blanks are parted-off brass bar but discs cut from 1⁄8in brass sheet can also be used. Nickel silver unplated, would be preferable but it is neither cheap nor easy to come by. (Complete details of the method appeared in my articles in Model Railway News June/July 1959, which may be got from your club or Municipal library or your own or friend's collection).

Romford non-insulated wheels can be used but squaring the split axle ends is difficult without the correct jig. Instead, I bore the wheel centre out, press in a piece of brass or nickel silver, bore this to 1⁄8in diameter and press the wheels on in the usual manner. If the treads are to be to EM fine or P4 standards, press the coned wheel centre out of the rim from the front using the tailstock barrel, wrap a piece of aluminium cooking foil round the centre and press the rim back again. It will now protrude at the front and can be thinned down and the wheel back machined flush to give scale width and the flange can be reduced as desired.

Wheels with plastic centres can be shorted as figure 5. Bore out the centre as large as possible, file two slots .02in x .003in deep at 180 degrees in the back of the tyre and solder two strips of .02in wide x .002in thick brass shim therein so as to overlap at the bore. Press in a flanged brass bush .003in oversize from the rear so as to trap the ends of the shims between the plastic bore and the bush. Use a little Loctite 601 or similar for security but don't put it on the brass strips or you may insulate them. For plastic wheels having a brass bush in the centre, saw a slot across rim and bush along the spoke backs using a fine fretsaw then solder in a 36 s gauge plain copper wire at both points on rim and bush. File flush. You will not harm the plastic if you use a small, hot iron, do not hang about and put the wheel face down on a wet cloth as a heat sink.

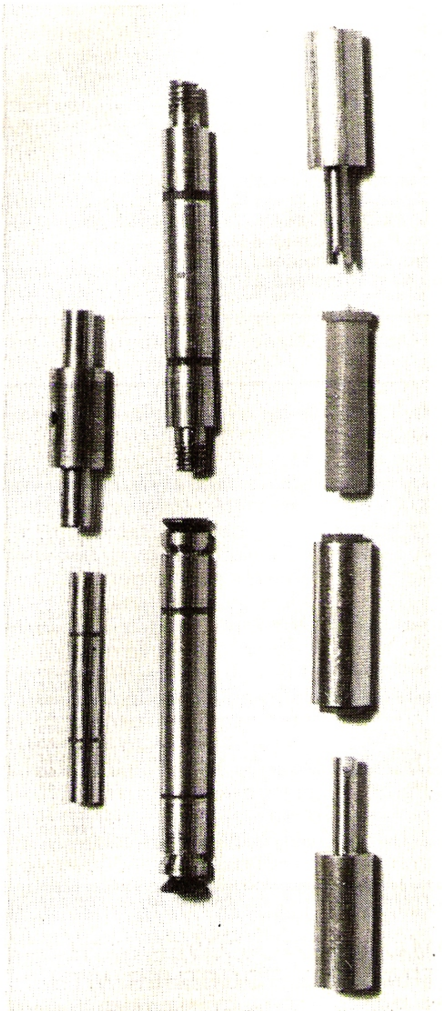
Motor protection

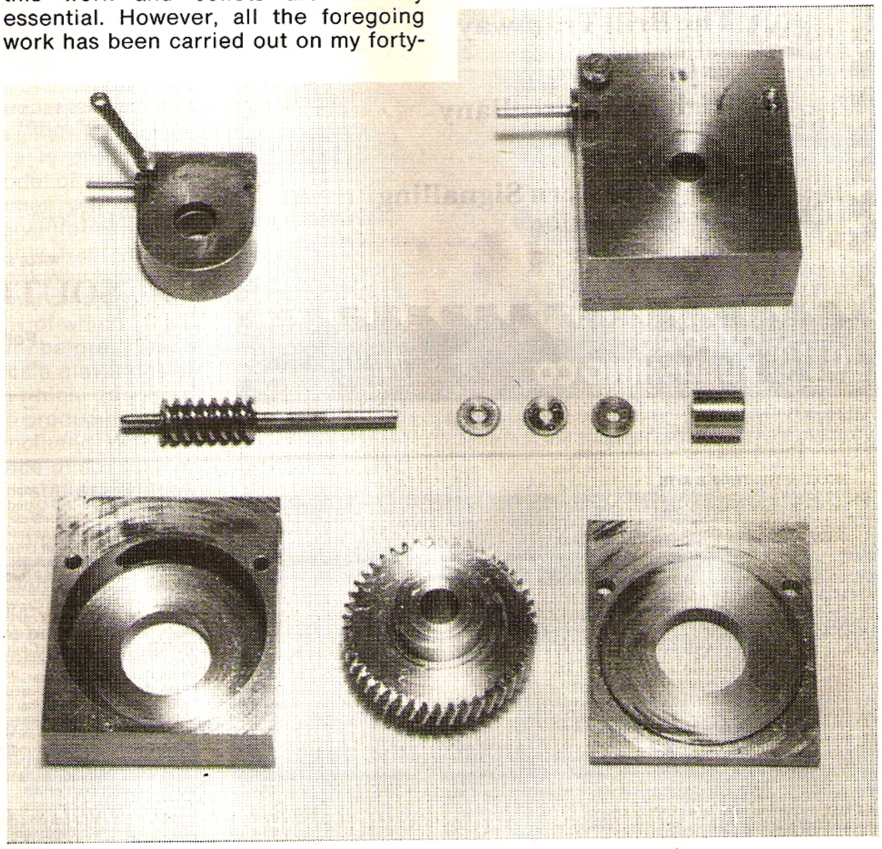
Current is fed to the O gauge loco via 2-1 watt 10 ohm resistors, one to each terminal. These have no noticeable effect on the loco performance but they do protect the motor against burn-out should a jam occur. Probably the only time that this will happen is when a crank pin comes loose and falls out – which it should not if you have done your work properly. Since the EM locos run on 24 volts, 100 ohm ½ watt resistors are fitted as protection. They get hot on stall but not excessively so. Even the O gauge loco, which is fairly heavy, can slip its wheels so there is no stall problem from train overload. The O gauge engine hauls six heavy Exley coaches on the level taking 0.25 amps. The two EM engines haul ten bogie coaches up my 1 in 80 on 0.06 amp. Limited adhesive weight then permits slipping. With sufficient weight 100 wagon trains would be a simple matter and I doubt whether the current would exceed 0.1 amp. It will thus be seen that these are three very efficient locos indeed and the information is published for the assistance of other modellers.

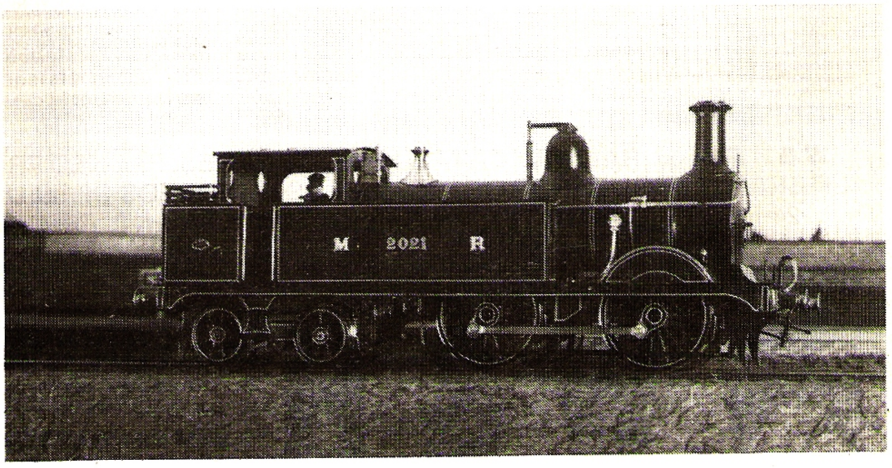
Tailpiece

One obviously needs a decent lathe for this work and collets are virtually essential. However, all the foregoing work has been carried out on my forty-year old Myford ML2 which costs £8.25 new.

I made my own collets years ago. My oldest loco with split axles has run without problems for thirty-six years and the first gearbox has now clocked up thirty years, both putting in many hours of exhibition running so I can claim them to be fully developed and reliable. They will certainly outlast me. This article is, of necessity, very brief but I shall be happy to answer any questions arising therefrom. The lovely paint job on the O gauge engine is the work of Larry Goddard. My old photographer colleague, Gerry Catchpole, took the pictures. PMR







Above: *A group of split axles.* ***Left:*** *Two types of EM.* ***Middle:*** *O gauge axle ready for squaring and one with screwed ends.* ***Right:*** *Parts of O gauge axle.* ***Top right:*** *The top row shows an EM and O gauge gearbox with torque arm fitted to the EM one. Below are the worm, thrust bearing, worm wheel and casing of an O gauge gear box.* ***Right:*** *The O gauge Midland Johnson 0-4-4T*