May 1979 45p
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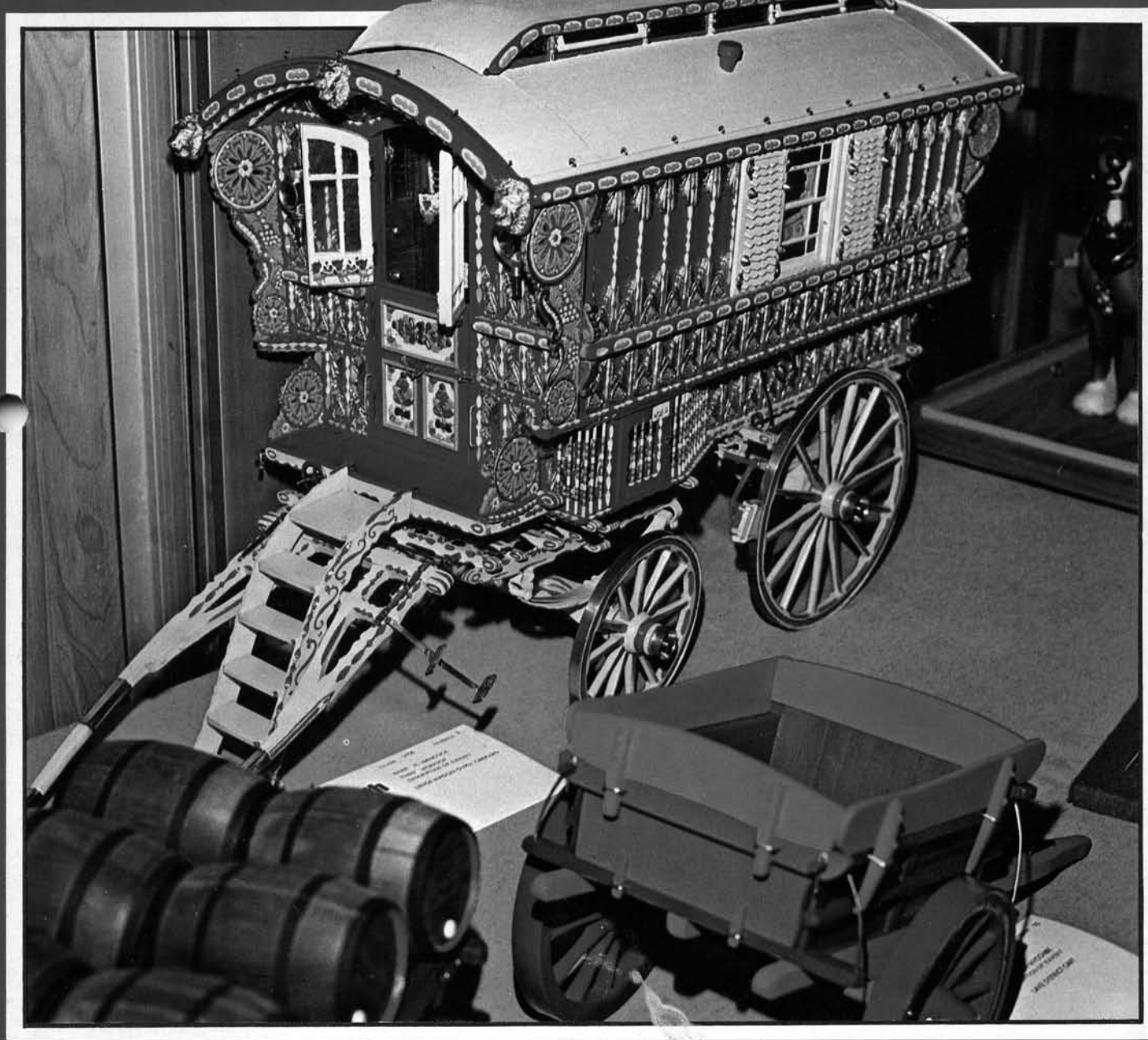
# Model Mechanics

MAP HOBBY MAGAZINE



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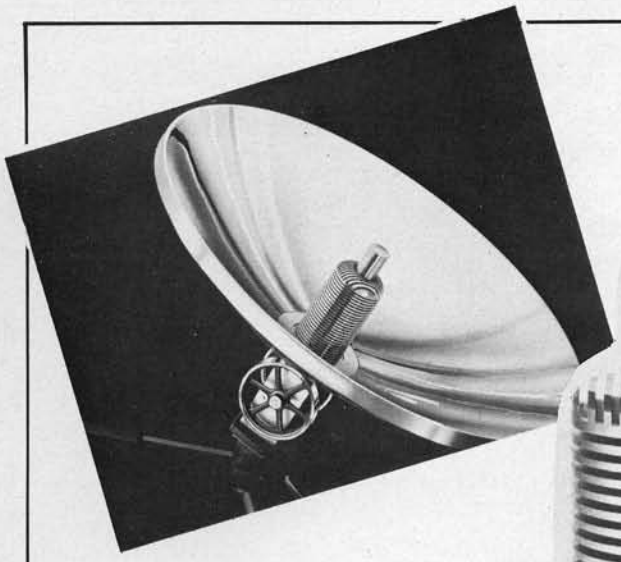

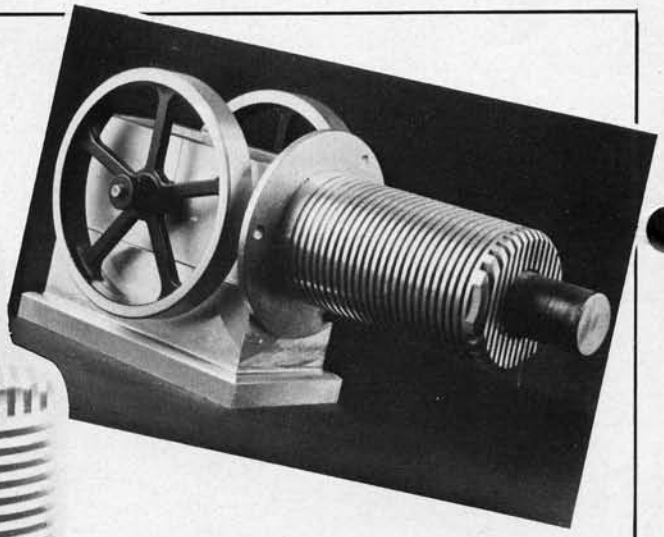

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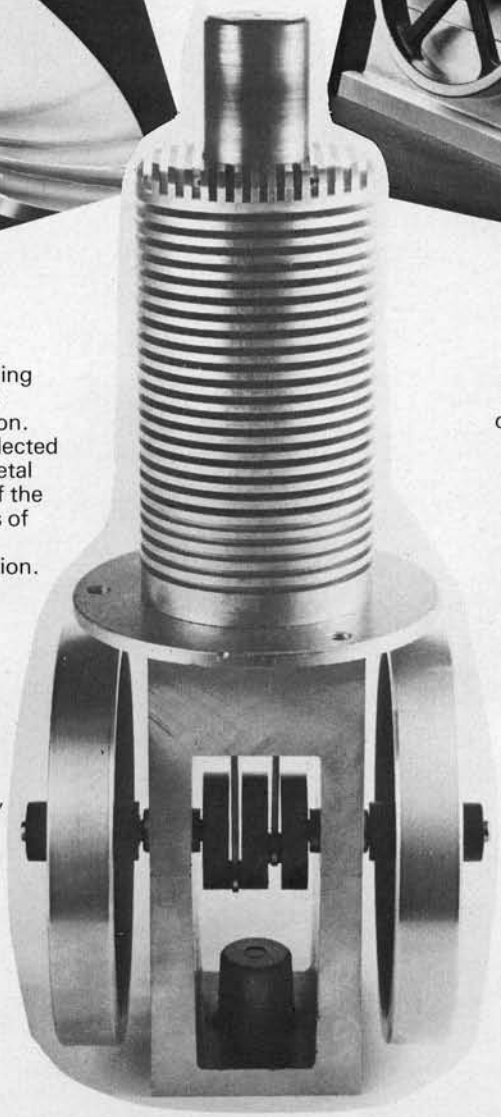

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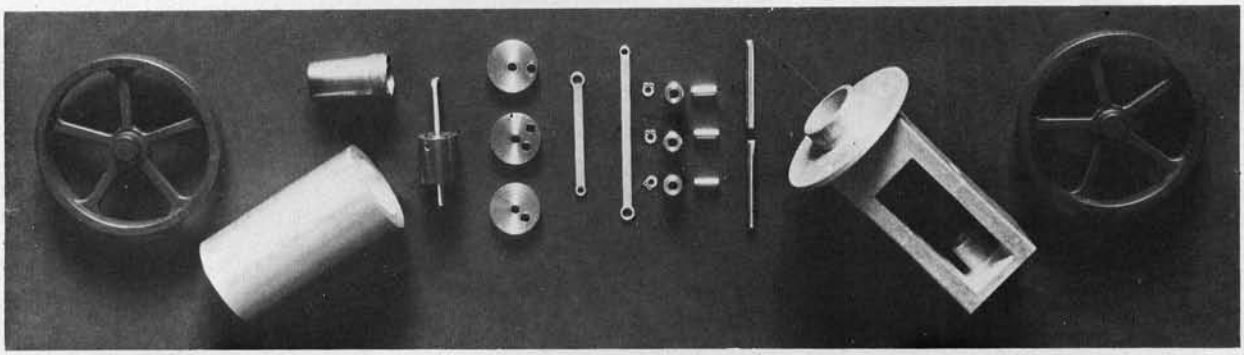

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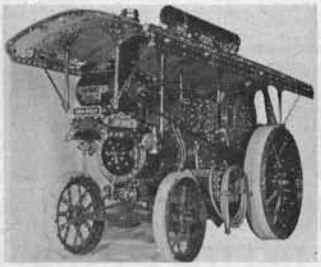
# Model Mechanics

VOLUME 1 Number 4 MAY 1979



Model of Lodge Wagon Gypsy Caravan by H. Hancock of Workshop. (Commended in Model Engineer Exhibition 1979). Photo by W. David Askham. In the foreground—Lake District Cart by J. Power of High Wycombe.



An example of fine model building by an advanced Meccano constructor. A scenic Showman's Engine by D. B. Holiday of London.

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# Editor's Chat

HOW MANY of you, reading last month's copy of *Model Mechanics*, decided that Eagle is the model for you? Martin Evans has promised us that he will explain all steps of construction fully for those of you who may never have attempted such an undertaking before. The more experienced model mechanics should meet nothing in the course of construction to upset him. With any model built from metal, the amount of work involved depends upon the workshop facilities available, but assuming that only basic equipment is at your disposal—and we are including here a small lathe, then the task set in the first instalment would have meant a few hours with a hacksaw and file at the workbench. Those of you with access to a milling machine will have probably had the frames finished in hardly any time at all.

Mind you, I rather enjoy using a file at times—although I recall that I never used to in hot weather—and I believe that it is essential to develop the skills required for hand tools. After all, you may need to do a job when access to machines is not available. Even so, there are some jobs which cannot be done without some form of turning equipment. This instalment of Eagle includes one of them—the wheels. Beginners to model locomotive building may not know that the section of a wheel—that is at the rim—is extremely important in the task of keeping the loco on the track. This is one of those jobs where the "that will have to do" attitude, I am afraid, is not good enough. I have seen wheels built up from separate spokes soldered to the rim, but this is no task for a beginner. Castings will be available for these wheels and other parts, and there will be sufficient metal oversize to enable an accurate profile to be cut.

The drawings reproduced in *Model Mechanics* are taken from the full-size working drawings suplied to us by Martin Evans. You may wish to buy dye-line prints of thes drawings to use instead of exposing your magazine to the hazards of dirty hands. As each sheet is completed and put into the Plans Service we will let you know, and it can be ordered from our Sales Department. Over the years, this has resulted in a comprehensive catalogue for model engineering and other activities. Doubtless you have seen the advertisments. Many of these plans came to M.A.P. from the publishers of *Model Maker* and other magazines when all these publications came under M.A.P.'s administration.

Looking back through old issues of *Model Maker* is a very enjoyable experience. If one were to make every model which appeals, I am afraid there would be little time left for other, perhaps more vital pursuits. One of these models is the hovercraft, a model which has never received its fair share of development, although a few years ago one or two kits were marketed. M.A.P. plans service publish a few hovercraft designs and we intend looking at them in the light of modern propulsion methods. When we have built and tested what we consider to be the best design, we will describe it in the magazine. Another model which has been neglected in the past is the motor cycle or scooter. Any working model and these have been very few, used out-rider wheels for stability.

However, even this has changed and we can now offer plans for a radio-controlled i.c. engine-powered scooter, which does not require stabilising wheels.

M.A.P. Plans Handbooks cater mainly for model scooter, which does not require stabilising wheels.

The Plans Handbooks cater mainly for model engineering, model boats, aeroplanes and radio control. The unusual type of model which does not readily fall into any of these categories finds its way into one or other of the form handbooks. We hope, soon, to add another handbook specially for the model mechanics. It will include models from other handbooks and, of course, new designs which appear over the next few months. It is possible that many of you have favourite models, which you have designed, built and operated. If you have, and you think others may be interested in them, we would be pleased to hear from you. Maybe your drawings will be accepted for our Plans Service, even if they are not, the model could still appear in *Model Mechanics*. At the same time, it will tell us more about our readers' tastes in models.


MG Midget TD series, designed for 1½ cc engines bevel drive to rear wheel and clutch detail shown. Plans book No. 2.

1900 De Dion. A really outstanding model car designed for .5cc engines. Plans book No. 2.

Columbine a simple 26½ in. cabin launch for up to 1½ cc diesels or electric power. Plans book No. 2.


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# Miniature internal combustion engines

by Geoff Sheppard

THE MODERN, COMMERCIALLY available miniature internal combustion engine is a highly developed and very sophisticated piece of engineering. You will note that I use the term "miniature" instead of "model". I do this because I take the same view as the late Master of the small steam locomotive world, "LBSC", did of his engines, that these are small power units, built to carry out a specific task, using exactly the same principles as those normally encountered in their larger counterparts.

With a specific power output of around 160 brake horse power (b.h.p.) per litre of cylinder capacity, these miniatures are certainly not to be categorised with the wares of the toyshop!

The ready availability of a wide range of engines to suit every need in the model making world, with an equally wide range of prices, has discouraged the building of engines by the amateur. For those involved in the competitive branches of power modelling, such as pylon aircraft racing, multi-boat racing or radio-control model car racing, the products achieved by the products of the large engine factories or a few specialist manufacturers would be difficult to match in a home-built effort.

Few have the skill, the resources or the time to embark on the sort of design and development programme which would be required to produce a reliable power unit which would challenge the best of the off-the-shelf engines. Consequently, there has been little stimulus for designers to publish their efforts, and apart from one or two notable exceptions, there has been little new since Edgar Westbury.

**Model Mechanics' aims**

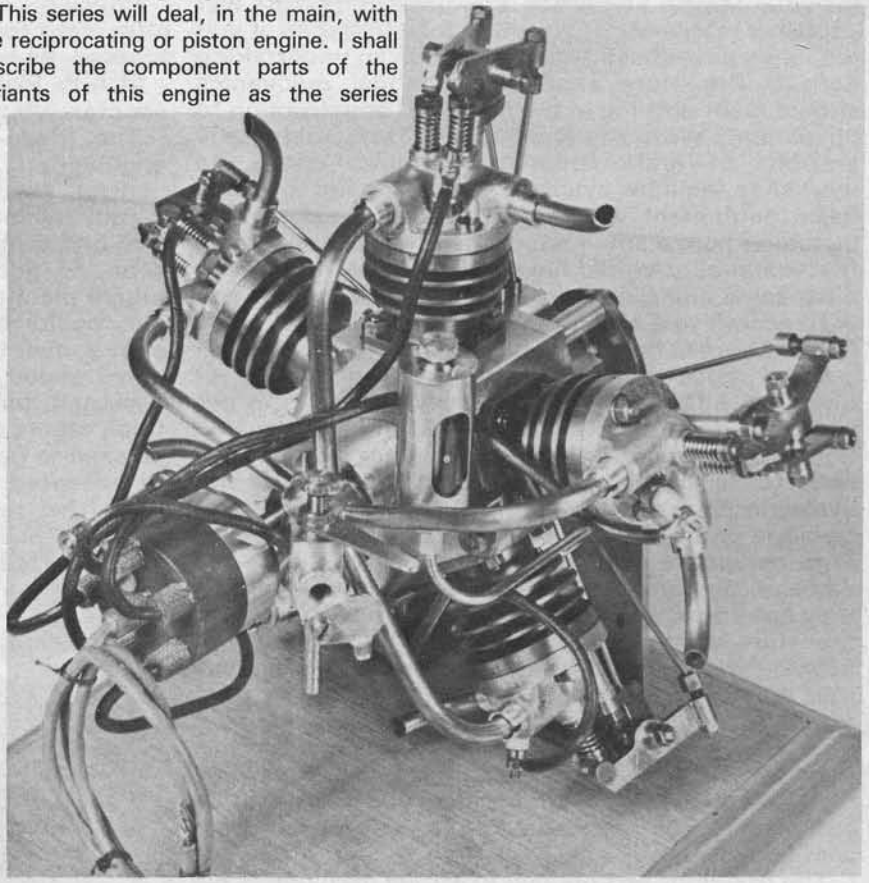
We are hoping to stop this decline in interest and to encourage readers to have a go at building small engines, also providing ideas for suitable applications. These will, of necessity, be simple at first, but later projects will increase the degree of sophistication. It is quite feasible to build a small i.c. engine on a light lathe, as there is seldom any very heavy machining to do. The larger structural components are usually in aluminium and the tougher parts are generally of modest size, so the owners of the Unimat, the Cowells and other makes of small lathes should find the job quite within their capabilities.

Before embarking on a constructional series, the plan is to introduce less experienced readers to the technicalities of the i.c. engine by describing the different types of engine which one may encounter, and the principles on which they work.

progresses, but the common feature of all

**The reciprocating engine**

This series will deal, in the main, with the reciprocating or piston engine. I shall describe the component parts of the variants of this engine as the series



*A four-stroke radial petrol engine made by Mr. L. C. Mason. Note the distributor*

is that they derive their power from the burning of a mixture of hydrocarbon fuel and air in a closed-end cylinder, the open end of which is fitted with a close-fitting piston. The increase in pressure caused by the burning of the mixture exerts a force on the piston which is driven towards the open end of the cylinder (or conventionally "downwards"). The linear motion is converted, via a connecting rod and crankshaft into rotary motion. A flywheel on the crankshaft stores sufficient of the energy produced to return the piston to the "top" of the cylinder for the process to be repeated.

**The operating cycle**

The sequence of operations taking place during the functioning of a heat engine is known as the thermodynamic cycle. The usual form of illustrating the cycle pictorially is a graph of the pressure in the cylinder plotted against volume. The fundamental cycle was first described by Carnot in 1824 (Fig. 1). This is an ideal, reversible cycle which is assumed to suffer no losses through friction or heat loss, so it cannot therefore be attained in practice. The modification to this cycle postulated by Otto (Fig 2) is the practical version and is the one on which the engines we are considering operate.

**Types of Engine**

The miniature engines we are considering fall into four main categories, depending on whether the thermodynamics cycle is completed in 4 strokes (2 crankshaft revolutions), of the piston and the method of ignition (and hence type of fuel used).

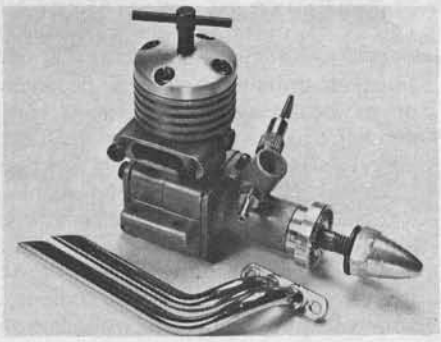
These categories are:

(1) 4 stroke, spark ignition (petrol fuel)
(2) 2 stroke, spark ignition (petrol fuel)
(3) 2 stroke, glow ignition ("glow fuel")
(4) 2 stroke, compression ignition (diesel fuel).

The four types differ in their design and construction to varying degrees and will be described individually. For simplicity, only the single cylinder unit will be considered.

**Four Stroke, Spark Ignition**

Although this is the least often encountered member of the small engine family, it is the easiest on which to explain the application of the thermo-dynamic



*King cat Diesel engine Diesel engine*

cycle, as all the events take place in sequence. In a 2-stroke, some take place in parallel.

The main structural member of the four-stroke engine, in common with the others, is the **crankcase.** Usually made from aluminium alloy, it can be cast or fabricated. It serves to house the **crankshaft,** which is mounted in the **main bearings** located in the case. The bearings may be plain bushes, ball races, roller races or a combination of these.

The crankshaft, of high tensile steel, has in the smaller engines, a single disc or triangular shaped member called the *web* at its inner end. the web carries the **crankpin** and is usually cut away to achieve a measure of counter-balancing.

This style of crankshaft is said to be "overhung", but larger engines may have a second crankweb in parallel to the first, with another bearing to the rear of the shaft to give increased support.

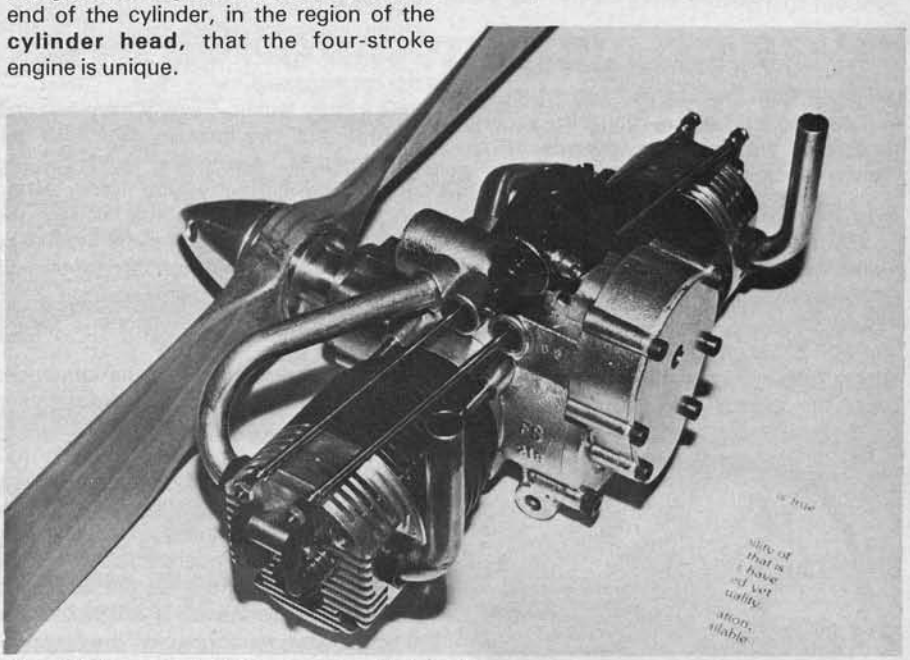
The **cylinder assembly** is attached to the upper face of the crankcase and has two main components. The outer member or **barrel** must have a means of disposing of the excess heat generated by the combustion process, so is finned in the case of an air-cooled engine or will have passages to form a water jacket. The barrel may be integrated with the crankcase or attached by studs. The second, inner component of the cylinder assembly is the **liner** usually of cast-iron or steel, in which the **piston** moves.

The piston, of iron or aluminium, usually has one or more **piston rings** which helps to maintain a gas-tight seal in the liner, and is connected, surprisingly (!) to the crankpin by the **connecting rod.** This component may be machined from solid or forged in duralumin, bronze or steel. It has a **big end** and a **little end.**

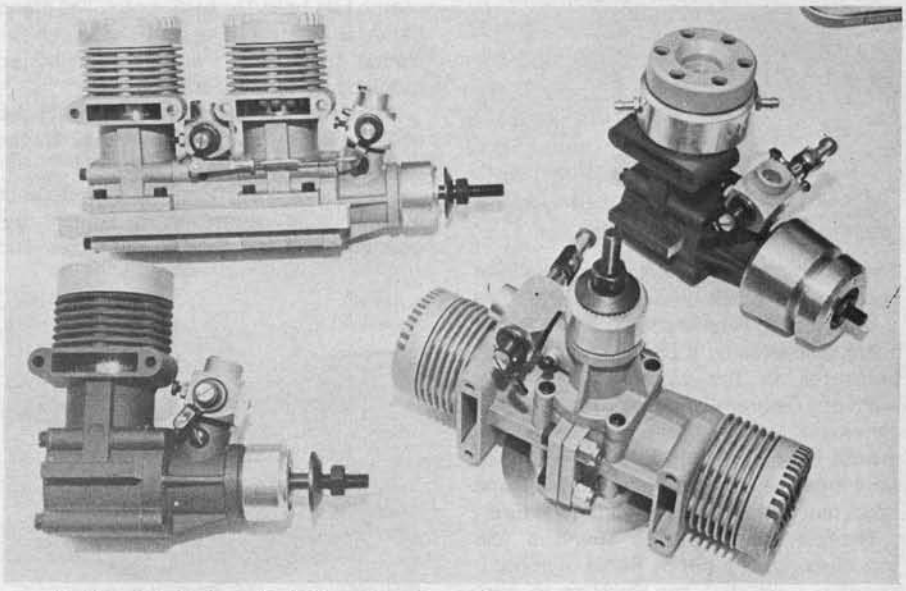
The big-end houses the bearing which runs on the crankpin. This bearing may be a bronze bush, be coated with white metal or, in the larger sizes, be a roller bearing. The little-end is the attachment to the piston, via the **gudgeon pin** (or, in some cases, a ball joint). To return to the big-end for a moment, the design is simple if the crankshaft is overhung, because the bush or roller bearing can be slid on to the crankpin, but in the case of a supported shaft, (and the majority of multi-cylinder engines) the big end must be split about a diameter, thus creating a **bearing cap** which is usually attached by high tensile steel **big end bolts** and nuts.

This restricts the designer to the use of a plain bearing, at this position, so if it is desired to use a roller race, as employed in many motor cycle engines, it must be possible to dismantle the crankshaft to remove the second crankweb while the connecting rod is being put into position.

All the above components are common in their general design to all four categories of engine, but it is at the upper end of the cylinder, in the region of the **cylinder head,** that the four-stroke engine is unique.



*Swedish Damo F.S.218 four cycle twin (glow)*



*A selection of British made "Meteor" glow engines*

Some means must be provided, in all types, of getting the petrol/air mixture into the cylinder and the burnt gases out. The **inlet and exhaust passages** terminate at the area above the piston, known as the **combustion chamber,** in **inlet and exhaust ports.** The ports can be sealed by **valves,** which have disc-like **heads** attached integrally to rod-like **stems.**

It is tne location, layout and method of actuation of the valves, which the heart of the four-stroke engine and which has fascinated and frustrated the engine designer since the turn of the century.

At this point it is pertinent to examine the working of the four-stroke cycle, so I will leave the description of the remainder of the engine until later. Returning to Fig. 2, I will describe each phase in turn, following the reference numbers round the cycle.

**0 to 1**

THE INDUCTION STROKE, is when the charge of mixture is drawn into the cylinder, by the action of atmospheric pressure, as the piston is withdrawn. (The distance of this line above the zero

pressure line represents, of course, atmospheric pressure). During this stroke, the inlet valve is in the open position, with the exhaust closed.

**1 to 2**

THE COMPRESSION STROKE, when the charge of mixture trapped in the cylinder by the closing of the inlet valve, is compressed by the rising piston. (The exhaust valve remains closed).

**2 to 3**

The combustion phase, when the charge is ignited (by the sparking plug), theoretically without any movement of the piston, so the pressure increases without change of volume.

**3 to 4**

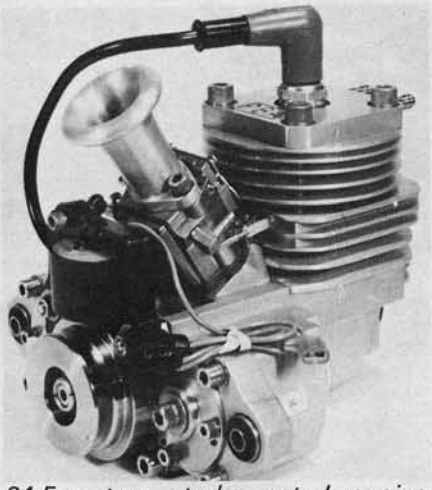
THE POWER STROKE, when the heat released from the burning fuel heats the air/gas mixture in the charge to expand and force the piston downwards. (Both valves will closed).

**4 to 1**

The release phase, when the exhaust valve opens (at 4) allowing the burnt gases to drop to atmospheric pressure.

**1 to 0**

THE EXHAUST STROKE, when the rising piston forces the burnt gases out past the exhaust valve to atmosphere.



*34.5cc two stroke petrol engine, designed by Mr P. B. Allen.*

The exhaust valve now closes as the inlet opens ready for the next cycle.

In practice, even the Otto Cycle is not achievable exactly, a practical plot of the pressures in the cylinder (called an Indicator Diagram) will look more like that shown in Fig. 3, because none of the events happen instantaneously—it takes time for valves to open fully and the flame takes time to spread through the mixture.

Here, I would like to spend a few moments riding a hobby horse of mine. It is often said that the fuel/air mixture explodes in the combustion chamber. It does not (or at least it shouldn't)! Under ideal conditions, a flame should spread through the gas, emanating from the points of the sparking plug, with the flame boundary propogating steadily outwards until all the fuel in the charge is burnt. As I said above, this takes time, so the spark is timed to occur a little before the piston reaches the top dead centre, so that the full benefit of the expansion of the charge is available as soon as the power stroke starts.

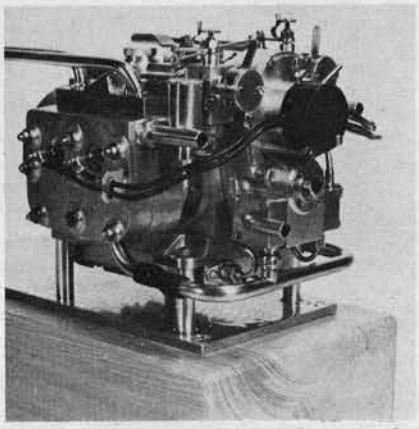
Of course, this rate of flame propogation is the same, whatever the speed of the engine, so as the speed increases a means is required of igniting the charge at an earlier stage of the compression stroke. This device is termed the "Advance and Retard mechanism". Those familiar with vintage motor cars will recall that a lever was usually provided, often on the steering column, for just this purpose. This allowed the driver to rotate the body of the ignition distributor (more about ignition systems later) to achieve the earlier ignition timing as the speed of the car increased.

Our early Austin Sevens have just this feature, but the later models have the new-fangled "Automatic Advance and Retard", where centrifugal force, acting on a system of weights within the distributor, performs the same trick. (The trouble with the manual system is remembering to retard the ignition when suddenly slowing in a modern traffic-jam!).

All the above describes the conditions for perfect combustion, but under certain conditions of pressure and temperature in the combustion chamber, a given fuel **will** explode, the phenomenon being known as detonation or "knocking" (from the sound it produces). This leads to overheating and overstressing of the engine. As one of the factors leading to increased performance is an increase in the average pressure in the cylinder during the power stroke (the Brake Mean Effective Pressure or B.M.E.P.), the search has been for fuels which will stand higher B.M.E.P.s. The result has been the leaded fuels which are now giving so much cause for concern.

After that diversion into the intricacies of combustion and ignition, back to the mechanics of the four-stroke.

As can be seen from the sequence of events, it is necessary to control the opening and closing of the inlet and exhaust valves precisely. The device employed to do this is the CAMSHAFT. This shaft is driven from the crankshaft by a system of gearing, by chains and sprockets or by toothed belts, depending on its location in the engine. It has a number of raised portions or LOBES at intervals along its length, such that there is one lobe for each valve, in the engine. A follower or TAPPET bears against each lobe, and the resulting oscillating movement is transmitted by a linkage to the valve. In the majority of engines, a strong VALVE SPRING (surrounding the valve stem) is used to keep the tappet in contact with the lobe of the cam, so that both the opening and closing of the valve is under control. A study of the valve opening and closing sequence will reveal that this camshaft needs to revolve at precisely half the crankshaft speed. This is, of course, achieved by the drive system.



*Mastif 24cc four cylinder, four stroke, water cooled engine. This one was made by Mr Dempster.*

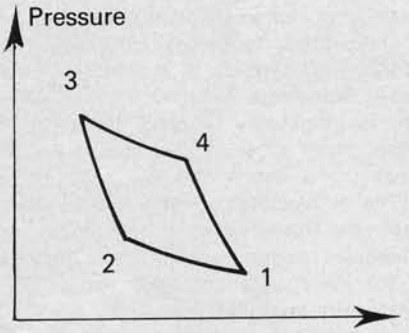



*Fig. 1. Carnot Cycle*

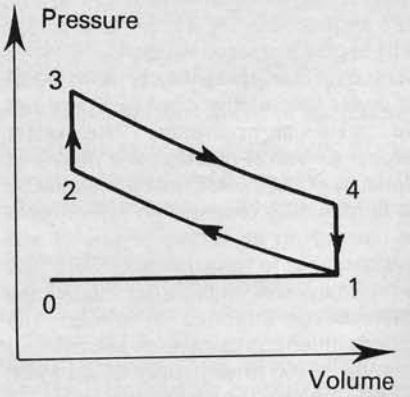



*Fig. 2. Otto Cycle*

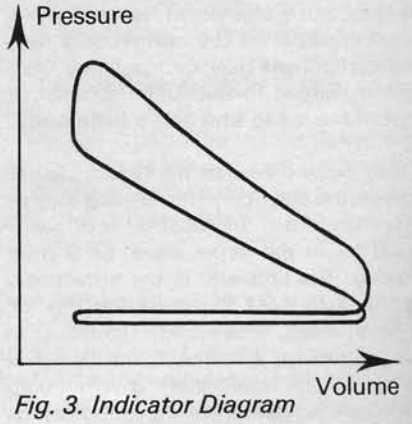



*Fig. 3. Indicator Diagram*

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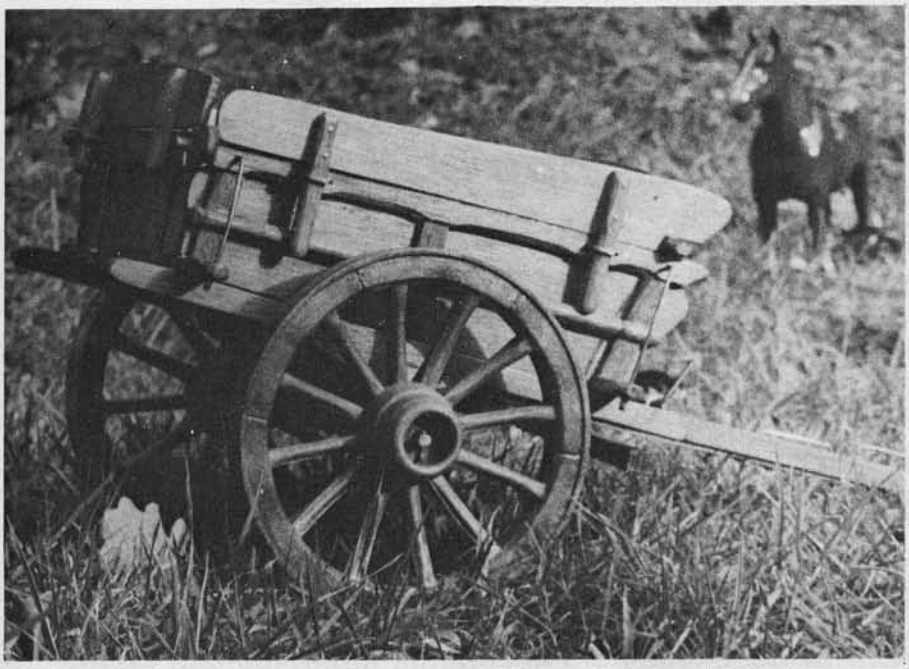


## Making a model cart

**There is a very special satisfaction in working with wood, and by modelling farm vehicles, you can enjoy recreating in miniature some of the heritage of craftsmanship handed down to us by the wheelwrights of rural England.**

THIS MODEL IS a good introduction to the hobby, because it can be made without special tools, and from materials you can obtain at local shops.

Beginners are sometimes deterred by the prospect of tackling the wheels, and indeed a lathe and some special jigs are needed for this, so subject will not be dealt with in this article. Initially, the difficulty can be avoided by purchasing the wheels ready made, and suitable moulded composition wheels for this cart are available.

Although a straightforward model, this cart is a true replica of the actual vehicles which were used in the Lake District and the result is a vast improvement on the crude toys seen in some gift shops. If you wish to display a horse with the model, it is best to buy it first, so that you can tailor the shafts to fit. The medium-size horse, about 7 in to the back, will be correct for this $\frac{1}{10}$ th scale model.

**General Notes**

The view on page 197 shows how the cart is constructed and the plans on page 198 show the patterns for cutting each part. These patterns are printed at one-half full size, so you need to double all the sizes to mark out the timber, using dividers.

The sizes of timber have been chosen to line up with those you can buy in D.I.Y. shops, most of which sell the hardwood 'ramin' in small strips.

Alternatively, you could use balsawood from a model shop, or prepare your own timber.

The model is assembled using a wood glue, such as Evostik Resin W. Any excess glue should be wiped off with a damp cloth before it dries, otherwise it will show as a white patch under the varnish.

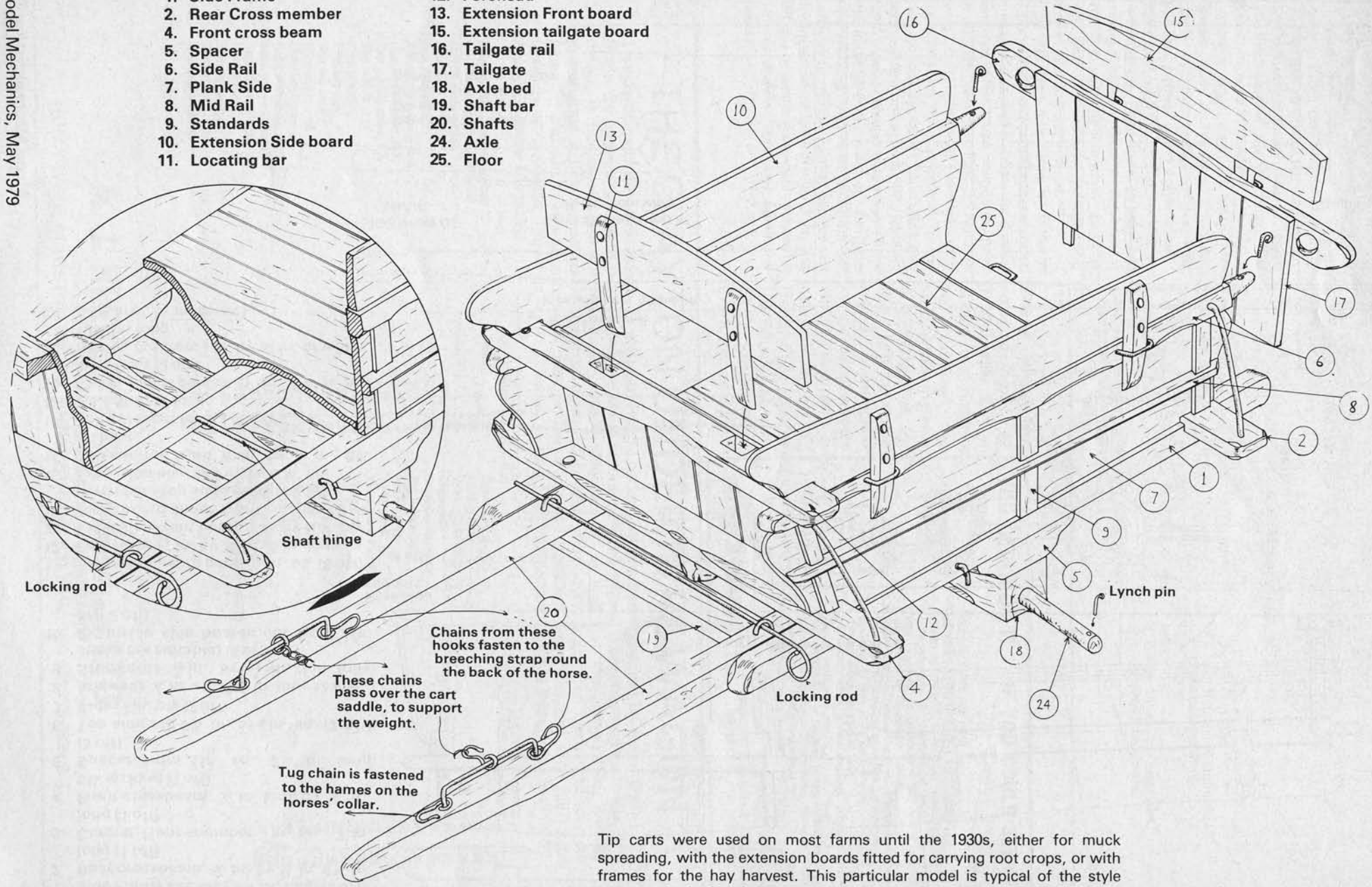
To strengthen the joints and for appearance, pins may be used in addition to the glue. The brassed escutcheon pins sold by most ironmongers look attractive, but you must drill holes before pushing them in. Do not try to use them as nails, or the small sections of wood will split.

A small saw, such as a junior hacksaw is needed to cut the wood and wire to length. A craft knife is used to shape the wood and sandpaper to give a smooth finish. A drill ($\frac{1}{16}$ in) is required for the holes and pliers for bending the wire. A set square, rule and dividers are useful in marking out.

**Step-by-step instructions**

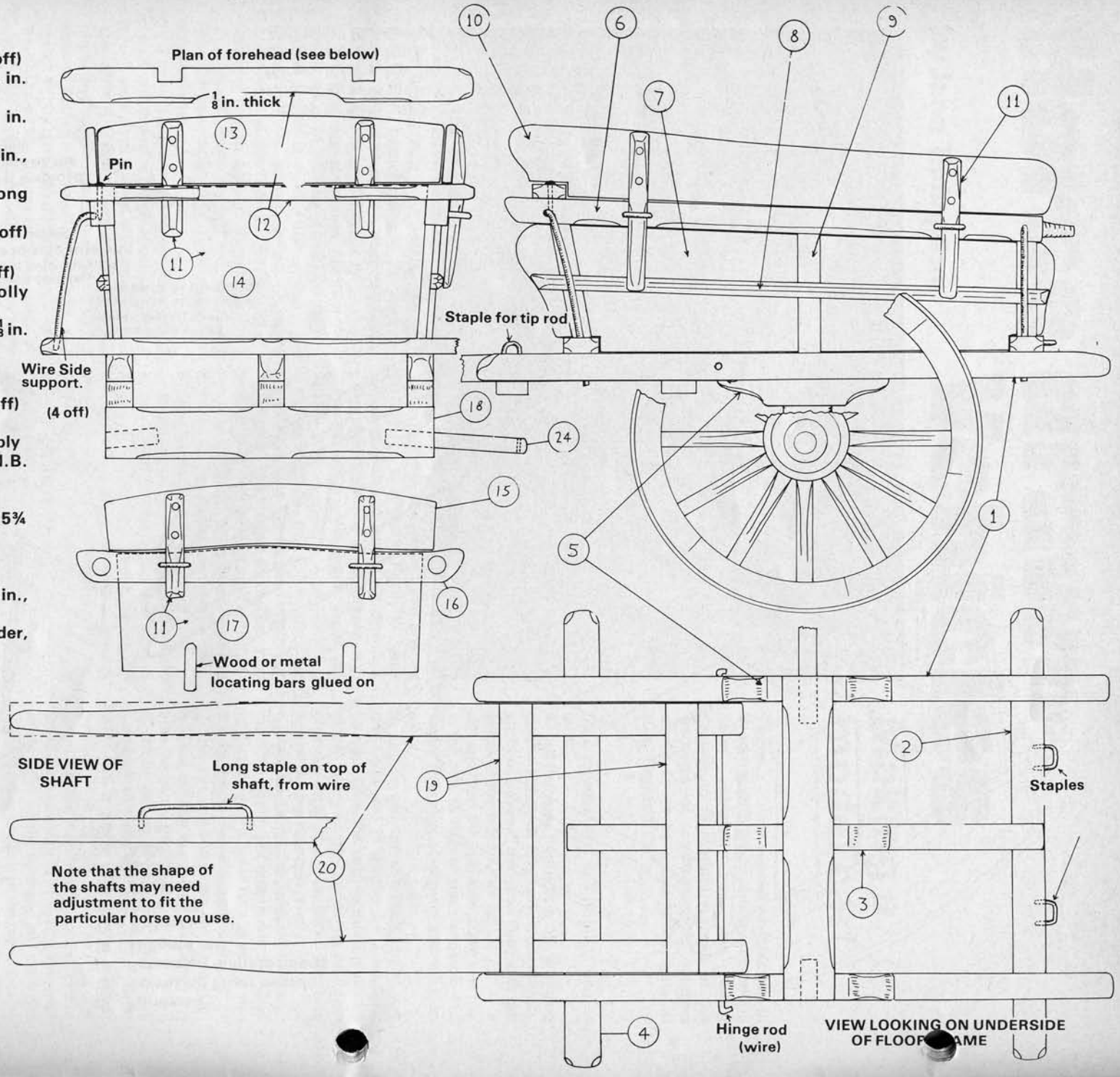
1. Cut out parts 1, 2, 3 and 4. Shape the ends (you can cut the decorative chamfers with the craft knife) and sandpaper smooth.
2. Cut a piece of plywood, $\frac{1}{8}$ th in or 3mm thick, and 6 in by 4½ in, for the floor. The grain should go across the wood, so that lines can be scribed to represent the plank joints. Make these ½ in apart, using the back of a craft knife against a straight edge.
3. Lay out the floor frame parts so that the plywood comes half-way across each of the side members (1), and butts up against the cross-members (2) and (4) with the central member (3) underneath. Glue together and drill at joints and fit pins.
4. Cut the sides from $\frac{1}{8}$ th in ply, and glue on the standards (9), made from ice-lolly sticks or similar. Trim these flush with the edges of the sides. Offer up the mid-rails (8), and mark the positions to cut notches in the rails to fit over the standards. Cut these, chamfer as shown and stick in place.
5. Cut the side top rails (6), chamfer and drill holes and fit staples for extensions boards. Glue the rails to the top of the sides, with elastic bands to maintain pressure while the glue sets. The side assemblies are now complete.
6. Make up the tailgate, with the rail glued onto the board, but do not drill the holes in the rail yet. Fix small bars to locate into the staples on the rear cross-beam.
7. Cut out and shape the forehead (12), and cut out the frontboard, but leave it a little oversize, to trim later.
8. Now do a 'dry-run' of the body assembly to make the final adjustments. 'Blue-tac' is useful to hold the parts in position. Locate the sides against the edges of the floorboards, offer up the frontboard and trim to fit exactly between sides. Offer up the forehead and mark out and drill holes to pin it to the top side rails. Offer up the tailgate, make the position for the holes in the tailgate rail to fit over the ends of the top side rails and drill out to fit. Drill holes for wire side supports.
9. Now the body can be glued together with the tailgate and forehead to locate the sides. When glue is dry, fit the wire side supports, and cut the bolsters (5) and glue them under the body.
10. Cut and shape the axle-bed (18), and drill holes for the ¼ in dia. axle arms, at a slight angle as shown. Drill small hole in arm for pin to secure wheel, and glue axle in place.
11. Cut the shafts and shape them to suit any particular horse model you are using. Join the two shafts by glueing and

1. Side Frame
2. Rear Cross member
4. Front cross beam
5. Spacer
6. Side Rail
7. Plank Side
8. Mid Rail
9. Standards
10. Extension Side board
11. Locating bar
12. Forehead
13. Extension Front board
15. Extension tailgate board
16. Tailgate rail
17. Tailgate
18. Axle bed
19. Shaft bar
20. Shafts
24. Axle
25. Floor




Tip carts were used on most farms until the 1930s, either for muck spreading, with the extension boards fitted for carrying root crops, or with frames for the hay harvest. This particular model is typical of the style common in the North East, and the plans are based on the example in the Abbot Hall Museum of Lakeland Life, at Kendal.

1. Side Frame $\frac{3}{8}$ in. sq., 9¼ in. long (2 off)
2. Rear crossbeam, ¼ in. by ½ in. 6¾ in. long (1 off)
3. Central Floor member $\frac{3}{8}$ in. sq., 7 in. long (1 off)
4. Front crossbeam, ¼ in. long by ½ in., 6¾ in. long (1 off)
5. Spacer from $\frac{3}{8}$ in. sq., 2½ in. long (3 off)
6. Top side rail 8½ in. of $\frac{3}{8}$ in. sq. (2 off)
7. Sides $\frac{1}{8}$ in. ply (2 off)
8. Mid-rails ¼ in. sq., 7½ in. long (2 off)
9. Standards $\frac{5}{16}$ in. by $\frac{1}{16}$ in. (ice lolly sticks are suitable) (6 off)
10. Extension side boards cut from $\frac{1}{8}$ in. ply (2 off)
11. Extension board bars, ¼ in. sq. (8 off)
12. Fore Head ½ in. by ¼ in.; 6 in. long
13. Extension front board 1 in. by 5 in. ply
14. Front board panel, from $\frac{1}{8}$ in. ply. (N.B. extends to top edge of forehead)
15. Extension boards 1 in. by 5 in. ply
16. Tailgate rail from ½ in. by ¼ in., 5¾ in. long
17. Tail gate, cut from $\frac{1}{8}$ in. ply
18. Axle bed, ¾ in. sq.
19. Shaft cross pieces ½ in. by ¼ in., $3\frac{7}{8}$ in. long (2 off)
20. Shafts, cut from $\frac{3}{8}$ in. by ¾ in. or wider, 10¾ in. long
24. Axle arm, ¼ in. dowel



pinning the cross pieces in place, making sure they fit snugly between the body side-frames. Then clamp or bind the shaft assembly in place and drill through both side frames and shafts for the wire hinge.

12. Cut out the extension boards, carve and fix the bars and offer up to body to mark out positions for staples.

13. After a final clean up with fine sandpaper, stain the wood to the shade you prefer and then apply varnish or wax finish. This natural wood appearance is probably best for a model built for display in the home, but if you prefer to paint it in the original colours then a blue body is appropriate, with the interior in red oxide primer and the wheels, shafts and extension boards in salmon red.

Once you have this model on show in your home, you will probably be plagued with requests to make others for friends or relatives. After these obligations have been fulfilled you can look forward to making more complex models and perhaps building up a collection of the various county types of farm cart and waggon. There are at least fifty distinct regional styles of waggon quite apart from all the trade vehicles, coaches, carriages and caravans, so you need never run out of subjects to model. Further articles will deal with some of the vehicles from this varied and fascinating selection. Please let me know if you have any particular requests.

**MATERIALS**

**Timbeer**

| | | | |
|---|---|---|---|
| (a) | $\frac{3}{8}$ in. sq. | Parts 1, 3, 5, 6 | 4 ft. 6 in. |
| (b) | ¼ in. sq. | Parts 8, 11 | 3 ft. |
| (c) | ¼ × ½ in. | Parts 2, 4, 12, 16, 19 | 4 ft. |
| (d) | ¾ in. sq. | Parts 18 | 5 in. |
| (e) | $\frac{3}{8}$ × ¾ in. | Parts 20 | 2 ft. |
| (f) | *2mm ply | Parts 7, 10, 13, 14, 15, 17, 25 | 8 in. × 18 in. |
| (g) | $\frac{1}{16}$ × $\frac{5}{16}$ in. | Parts 9 | 1 ft. (ice-lolly sticks will be suitable for this) |
| (h) | ¼ in. dowel | Parts 24 | 3 in. |

* Or 3mm (or $\frac{1}{8}$ in.) ply if 2mm is not obtainable.

**Pins**

Brass escutcheon pins, $\frac{3}{8}$ in. long, 6 doz. Also small wire for hooks etc.

**Wire**

$\frac{3}{4}$ ft. of 14 or 16 swg wire, or $\frac{1}{16}$ in. or $\frac{3}{32}$ in. brass rod if obtainable.

These plans are reproduced at 1/20th scale, so you should use dividers to double-up the sizes when marking out the timber for the 1/10th scale model. A complete kit including wheels and full size plans is available from W. Hobby Ltd., Knights Hill Square, London SE27 0HH, for £7.15, inc. postage.

# The Mechanic's Workshop

## Simple Woodworking Tools and their Care

By Andrew Smith

LAST MONTH WE discussed the fitting up of a bench for the workshop, so it would seem sensible to give some consideration to the tools needed to build the bench and the care and upkeep of these tools.

There are few households without some tools, however simple. And no doubt, you are reading this magazine because you have an interest in tools and like handling and working with them. It goes without saying that it is worth buying the best tools you can afford. This generally means that they should be well made, finished, and 'come nicely to hand', i.e. feel right. In addition, cutting tools must be made of the proper grade of steel and correctly heat treated if they are to work efficiently. This latter requirement is solely in the hands of the manufacturer, so it is important that we buy only tools bearing a known brand name which we can trust.

There are many tools of unknown make on the market, perhaps cheaper in price, but until we have gained some experience to help us in our selection, it is safer to buy a named make. After all, if it is unsatisfactory we can always return it to the manufacturer with our complaint.

Although you are setting up a mechanic's workshop, the first tools you will probably require will be for woodworking, to make the bench, shelves and cupboards. It will be a poor household that can't lay hands on a saw so we will start with that.

Wood-cutting saws come in two main types divided into "hand-saws" and "backed saws". The "hand-saw" is shown in use in Fig. 1, while a "backed saw" is illustrated in Fig 2. As you will realise, the latter is much shorter and is stiffened by a reinforcing backbone along its top edge.

From the point of view of use, a hand-saw deals with the larger aspects of wood-cutting, while a back-saw handles the finer details of cutting joints, etc.

Dealing with the hand-saw first; it comes in a range of sizes, usually 22 to 26 inches long and in two forms. These two forms are, first, for ripping wood longitudinally, in which case it is called a "rip-saw"; and second, for cutting across the grain of the wood (as being demonstrated in Fig 1), in which case it is called a "cross-cut" saw.

Reference to Fig 3 will give you some idea of the shape of teeth found on the two different types of handsaw. Notice

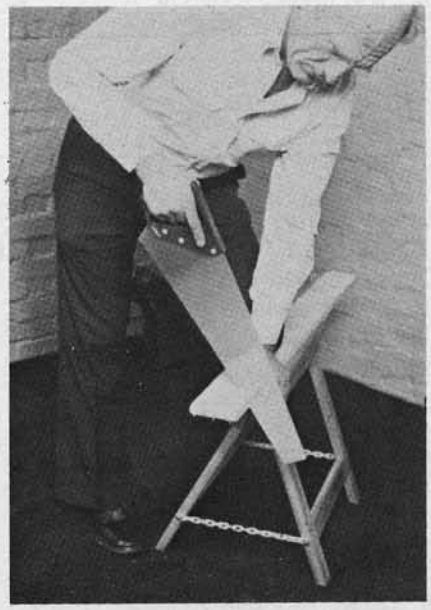


*Fig. 1 Handsaws may be for "ripping" or "cross-cutting" (as shown here) and are named accordingly*

that the teeth of the rip-saw are like a series of small chisels, each one cutting out a small groove along the grain of the wood. On the other hand, the cross-cut saw has teeth shaped to have sharp points that scribe two parallel lines severing the grain. The remainder of the tooth then removes the waste wood from between these two lines as sawdust.

Notice also that each tooth is bent or "set" alternately to the right and left so that the saw-cut or "kerf" is slightly wider than the thickness of the saw blade, thus allowing free cutting.

If you have raked out the old household saw from the garage or garden shed, it may well be in a rather dilapidated state and will need some renovation. The easy part of this will be to clean it (use fine emery cloth to remove rust), and tighten the screws holding the handle. The less easy part is to re-sharpen it, but with care this can be done and you'll have a saw as good as new.

First look carefully at the teeth and compare them with the shapes in Fig 3, deciding whether it is "rip" or "cross-cut". By the way, the relative coarseness or fineness of saw teeth are designated by quoting the number of "points per inch". This figure is often stamped at the back end of the blade.

The sharpening process is carried out with a double-ended file of triangular section. If you are buying one get it 7 inches (175mm) long. This will have a 6mm (¼ inch) side which should be large enough for any saw you may have to sharpen.

Clamp the saw between a couple of lengths of wood in the vice, with the teeth upwards. Lay the file between the first two teeth and at such an angle that it will reproduce correctly the tooth surfaces. Make say, six steady strokes of the file, carefully keeping it at the correct alignment. Now go to the next but one space between the teeth and repeat the performance with the file held at exactly the same angle. Continue along the length of the saw taking an equal number of strokes of the file between alternate pairs of teeth.

When you reach the end, reverse the saw in the vice and repeat the whole performance between the pairs of teeth omitted in the first pass. The teeth should now be sparkling like new and if you gently lay the palm of your hand on the teeth you will feel them pricking like lots of needles. If you draw blood, don't blame me!

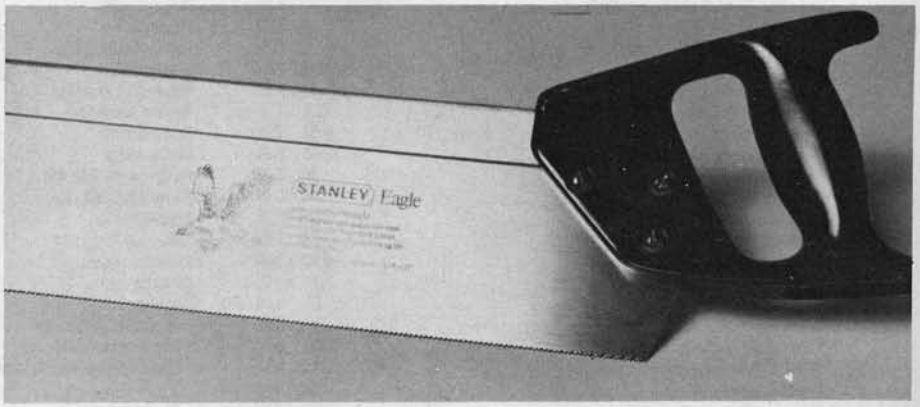



*Fig. 2 The back-saw. Depending on its size, it may be described as a Tenon Saw or a Dovetail Saw. The latter being smaller*

If some of the tooth points still look dull, then a second session of filing may be necessary. It may be that the saw is in a really bad state, with the teeth very irregular in height. If this is the case it is worth "topping" the teeth, that is, rubbing a large flat file along their tops to bring them all down to an even height before starting the sharpening operation.

After sharpening the teeth, try the saw on a scrap of wood. If it cuts freely you can congratulate yourself on a useful bit of renovation. If it tends to stick, the teeth need a little more "set" to allow them to cut a wider kerf.

In my younger days, when labour was cheaper than tools, we set saw teeth by laying the saw on a block of lead and, with a flat-ended punch and a light hammer, tapping each tooth over an equal amount. If you like trying traditional methods, a piece of softwood could be substituted for the block of lead.

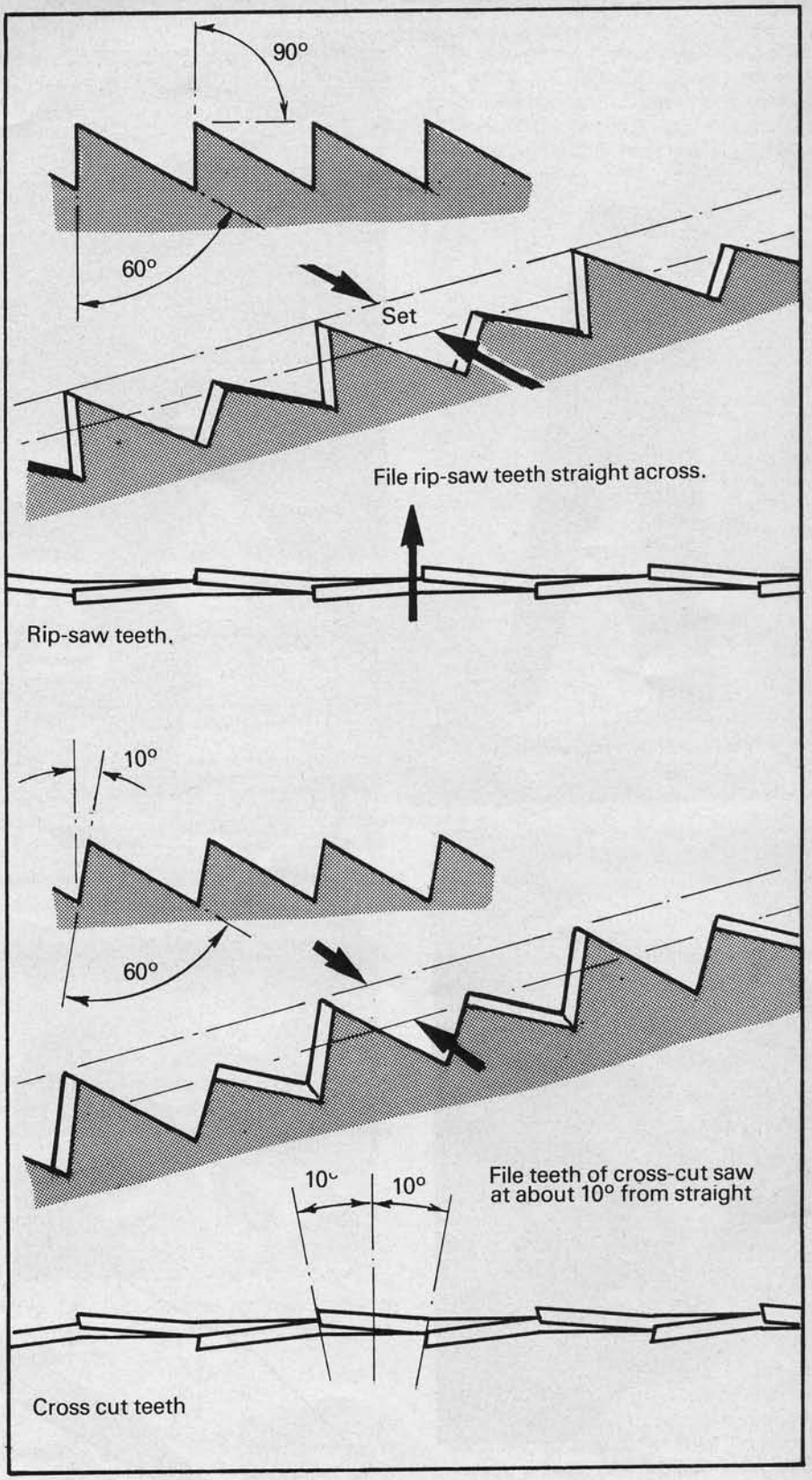
If you feel that your skill with a file is not quite up to the requirements described above, let me draw your attention to the tool illustrated in Fig. 4. This is a saw sharpener made by ECLIPSE suitable for saws having from 4½ to 15 points per inch, and using a replaceable 6-inch three-square (i.e. triangular section) file. Fig 5 shows the implement in use with the saw held between wooden jaws in a vice. There are five setting positions, so that various tooth profiles can be dealt with and the filing angle is automatically controlled. All you have to do is push the file back and forward.

To complete the picture, the plier-like tool shown in Fig 6, will accurately set the teeth of saws of from 4 to 12 points per inch. The process is shown in Fig 7.

Follow the instructions supplied with these tools carefully, they may differ slightly from those given above, and your woodsaw will regain the performance level it had when it left the manufacturer. Note, however, that these tools are not suitable for "hard-point" saws.

With a well-sharpened saw to cut the timber for our bench, the next need will be for a plane to smooth the sawn surfaces and a chisel to cut the joints.

Taking the latter tool first, Fig 8 shows the three main types of chisels used in the working of wood and their main purpose. Scrutiny of a new chisel edge will show it to have two different slopes. These are illustrated in Fig 9. The larger slope, at about 20° we refer to as the grinding angle, the smaller at about 30°, as the sharpening angle. It is the latter which actually has the cutting edge and which we need to resharpen. Hence when the chisel becomes dull, set the oilstone on the bench so that it won't slide about and smear the top with some thin oil. Then rest the cutting edge of the chisel on the oilstone tilted to an angle of 30° and carefully and steadily draw it back and forward along, as far as possible, the full length of the oilstone. Keep the angle constant all the time. If you find it difficult




*Fif. 3 Types of teeth and the methods of sharpening*

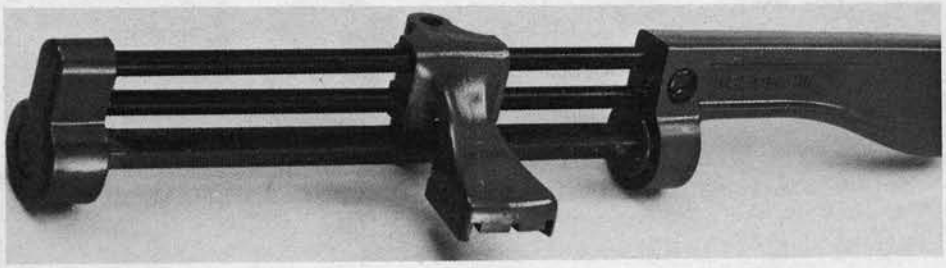


*Fig. 4 The Eclipse saw sharpener*

to maintain the correct angle, you may find the Honing Guide shown in Fig 10, just what you need. The demonstration photograph, Fig 11, shows exactly how to use this piece of workshop edquipment.

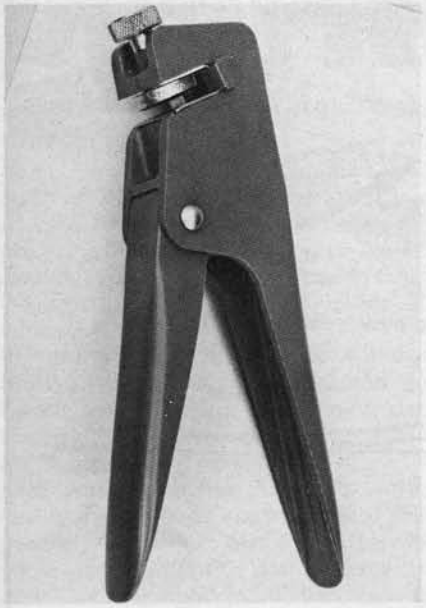


*Fig 6 The Eclipse saw set, will re-set most wood saws*

*Fig 7 The saw set in use*

After ten or a dozen firm strokes, run your finger along the back edge of the blade where you may feel a wire edge. If so, sufficient metal has been removed, so lay the back of the blade flat on the oilstone and rub back and forward three or four times to remove the wire edge.

There are an enormous range of different types and sizes of planes for woodworking. And believe it or not, some are for making the surface of the wood rougher—not smoother! However, the type shown in Fig 12 is probably the one

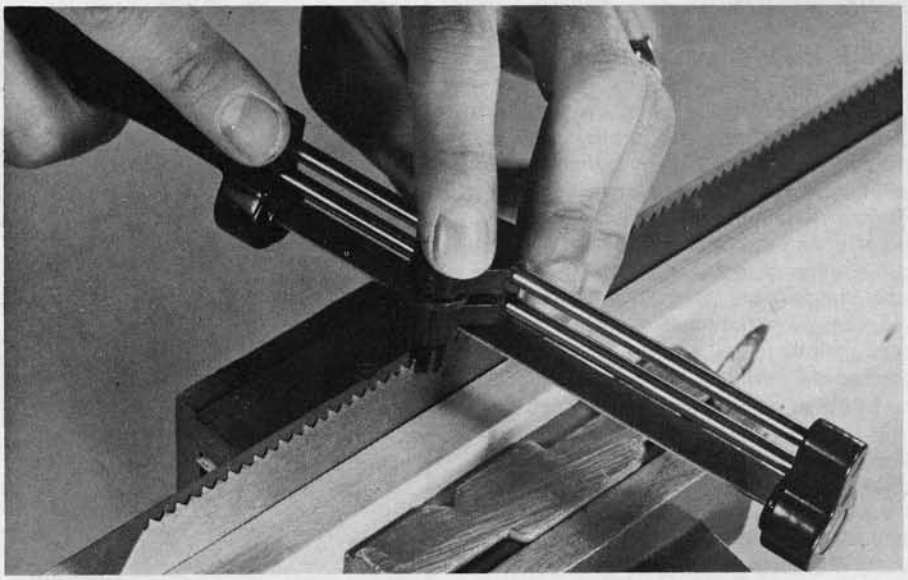


*Fig 5 Saw sharpening made easy*

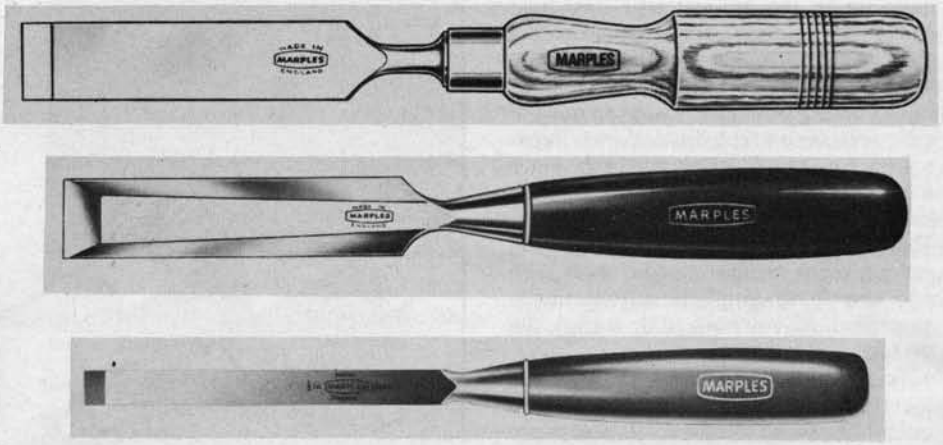



*Fig 8 Three types of chisel. Top A firmer chisel — the most commonly used. Centre a Bevel-edge chisel — used for paring corners when cutting joints and bottom a Mortise chisel for cutting Mortise and Yenon joints*

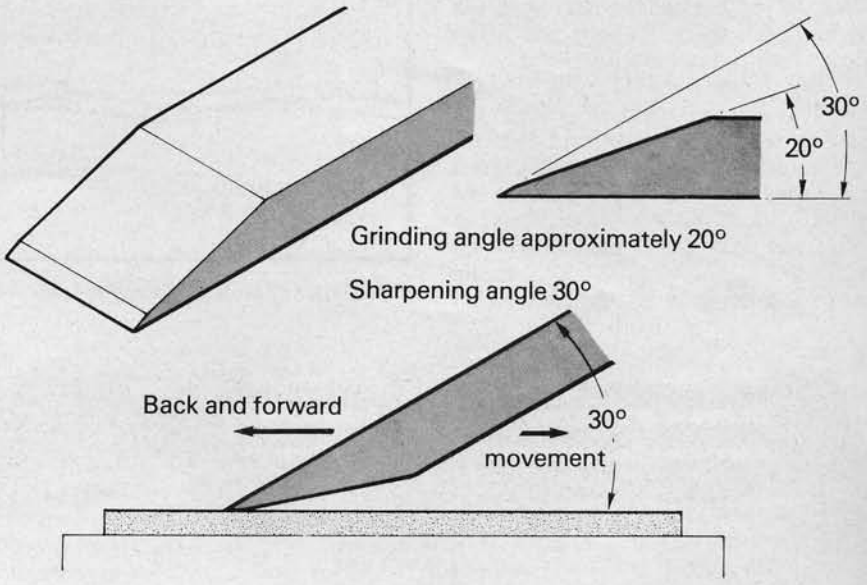



*Fig 9 Chisel sharpening details*


*Fig 10 The Eclipse Honing Guide for chisels and plan irons up to 65mm*

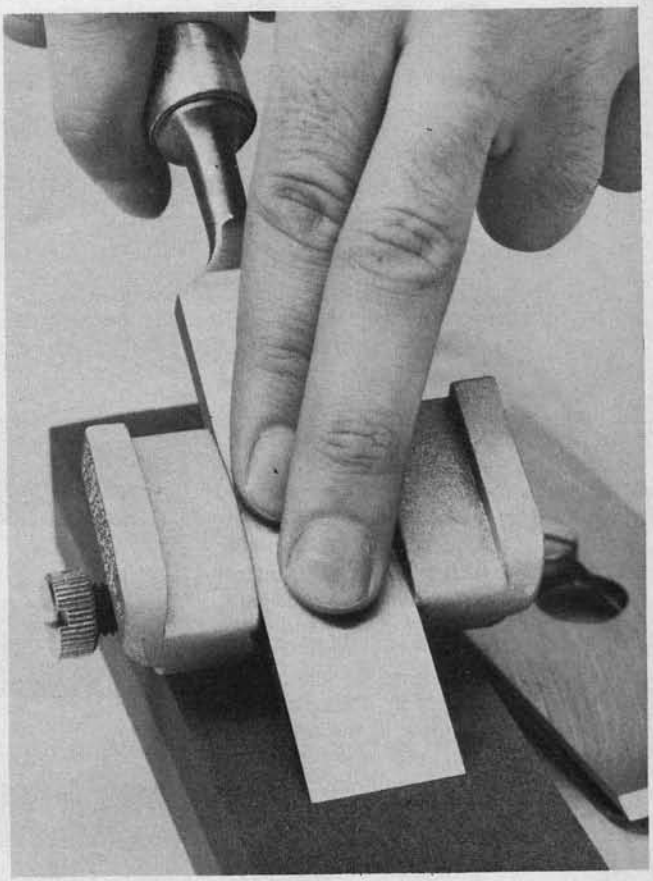


*Fig 11 The honing guide in use*

*Fig 12 Although described as a Smoothing Plane, this is commonly used for planing operations*

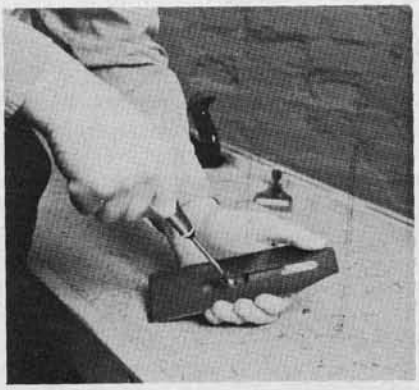


*Fig 13 How not to handle the assembly of blade and cap-iron*

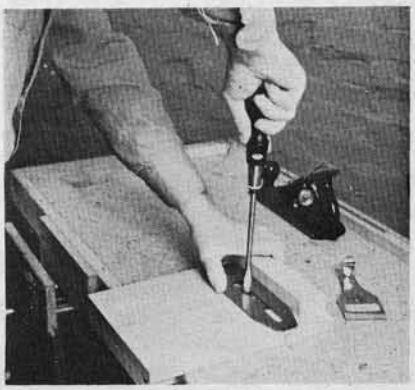


*Fig 14 Undoing the slotted screw to separate cap-iron and blade, prior to re-sharpening*

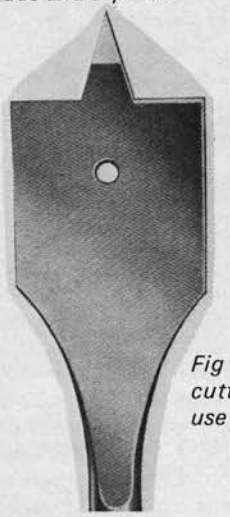


*Fig 15 A wood-cutting Flatbit, for use in electric drills*

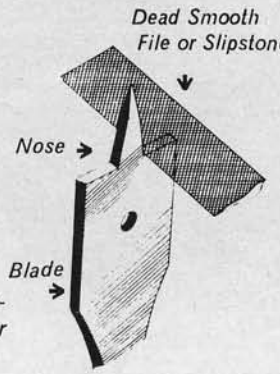



*Fig 16 Sharpening is carried out using a dead smooth file or oilstone. Take care to ensure that the original angles are maintained and that each side of the nose is sharpened equally. Do not file the sides of the boring diameter*

that will be most common in the home workshop.

**Plane blade**

Sharpening of the plane blade is exactly the same as for chisels just described and the above instructions should be followed. However, on dismantling the plane to remove the blade, it will be found to be stiffened by a "cap iron", whose purpose is to strengthen the thin blade and deflect the shavings.

A slotted screw holds blade and cap iron together. Fig 14 shows how the screw should be removed, NOT as in Fig 13.

When assembling the cap iron to the blade after the blade has been resharpened, have the edge of the cap iron not more than $\frac{1}{16}$in (1½mm) from the edge of the blade. If this gap is too great the plane will tend to "chatter", especially on hard woods, as the blade flexes under the force of the cut.

It remains now to consider the drilling of holes in wood. For small screw holes, etc., the common twist drills are generally used, especially if an electric pistol drill is employed. For larger holes, that is ¼in and above, the so-called "Flat-bits" are ideal. These must be used in electric drills as they are unsuitable for working at slow speeds such as would be obtained using a hand-brace. Fig 15 shows such a bit, while Fig 16 illustrates how simple they are to re-sharpen.

# CONSTRUCTION IN MECCANO

by Bert Love

. . . Bert Love, Secretary of the Society of Advanced Meccano Constructors, outlines the basic elements of engineering with the use of the most versatile system of construction ever invented. Beginning with a general survey of the essential components, the articles will show the beginner how to get started and how to develop his skills in utilising the parts to develop his own mechanisms.

WHEN FRANK HORNBY (famous for Hornby Trains!) invented the world-wide Meccano system with his introductory boxes of "Mechanics Made Easy" in 1901, he stumbled across a formula for modular construction which has stood the test of time and competition, almost by accident. Starting with simple trucks, hand-made with simple bench tools from copper sheet, he was seeking to standardise his parts for re-assembly in different forms and, while riding home in the train from his daily work in the meat trade in Liverpool, at the beginning of this century, his "½-inch module" system came to him as a flash of inspiration. By standardising the constructional elements of various lengths of strips in ½ in. widths and with holes at ½ in. spacing and by connecting everything up with standard Whitworth $\frac{5}{32}$ in. cheese-head bolts, he produced a system which survives to date. It is enjoying a popularity exemplified by adult societies at home and abroad putting on regular exhibitions of Meccano Models over a wide field of engineering and allied topics to a very high standard.

Despite decimalisation, these original modular standards are still maintained by the Meccano factory at Liverpool and Fig. 1 shows an original 1901 2½ in. Perforated Strip, made in tinplate with rolled edges compared with its stamped-out steel counterpart of to-day. They are, of course, basically identical. Right from the beginning, the perforated strip was the backbone of any Meccano Set and the ten different sizes from 1½ in. to 12½ in. are still available today. Fig. 1(b) shows a slight anomally to the basic module where a 1 in. strip, known in Meccano parlance as a "Fishplate",can be seen with one of its holes slotted. This feature adds to the versatility of the part, allowing it to extend a standard strip at a point of attachment on a diagonal for instance. Illustrated alongside is the modern 2 in. strip with yet another departure in having a ¼ in. spacing of the three centre holes making it a very adaptable component for centralising shafts etc. in compact gear boxes. Immediately below is the 2 in. Slotted Strip which not only permits adjustment when extending a standard length of strip, but provides a sliding slot for oscillating motion. It is from these basic strips and their variations in perforations that the whole Meccano system has evolved.

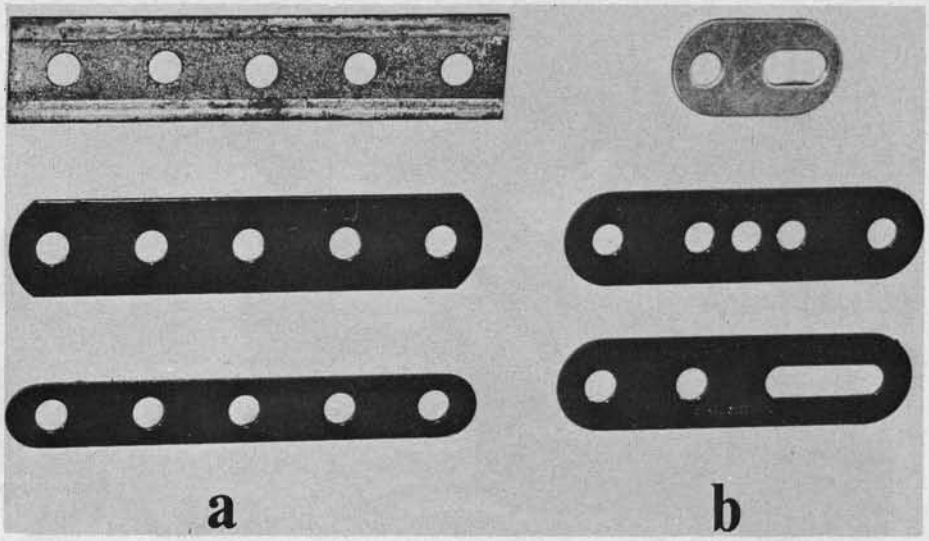



*Fig. 1*
*(a) Meccano 2½ in. strips spanning nearly 80 years. Top, rolled-edged tin plate 1901, middle, 1979 blue enamelled steel; bottom, 1979 "Narrow" strip.*
*(b) Variations in strip perforations. Top 1 in. strip or "Fishplate", note one hole elongated. Middle, 2 in. strip with extra centre hole a ¼ in. spacing. Bottom 2 in. "Slotted" strip.*

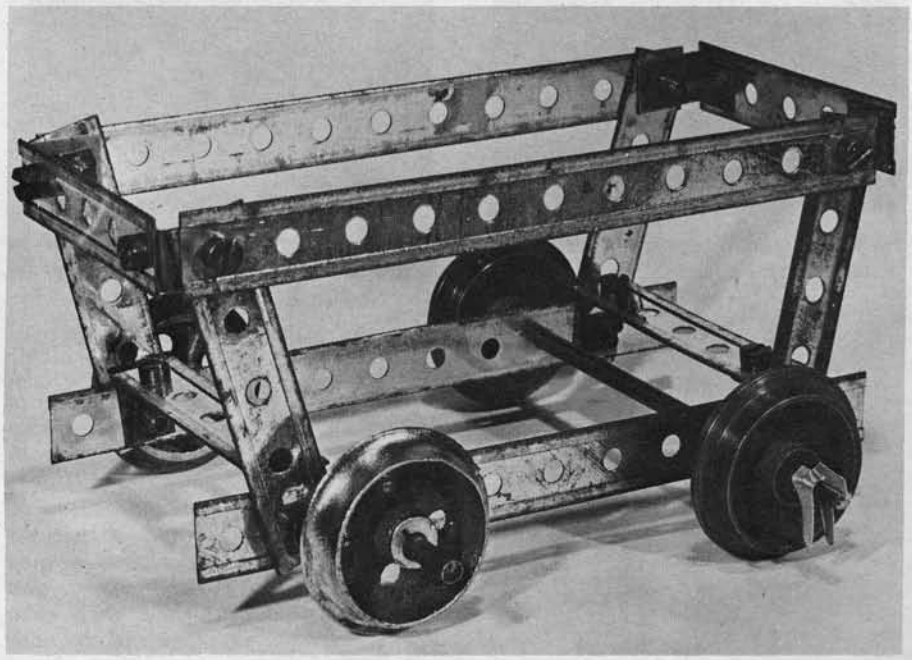


*Fig. 2*
*Earliest forerunner of Meccano waggon; a simple coal truck made from the contents of Frank Hornby's original construction kit, "Mechanics".*

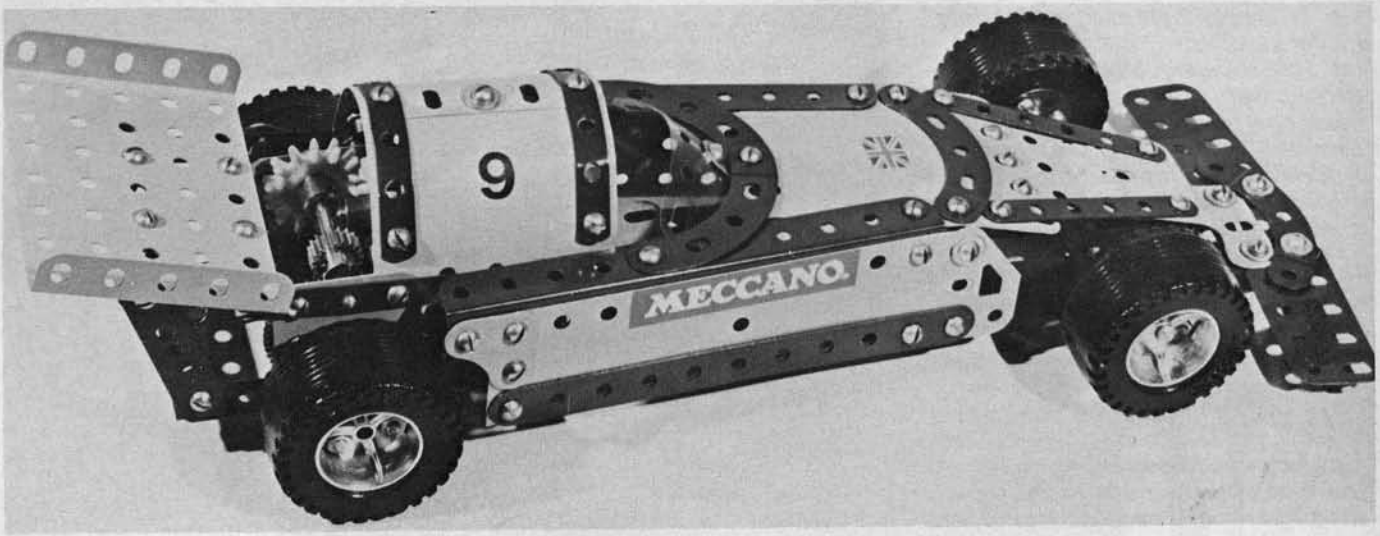



*Fig. 3*
*An up-to-date design by the author using the latest Meccano set No. 3. Striking outlines have added realism with the new Meccano road wheels.*

We can compare the advances made (still inside the basic concepts of Frank Hornby) by viewing the two models shown in Figs. 2 and 3. The crude open-framed railway truck was a feature model of the original tin box of "Mechanics Made Easy" produced by Hornby with simple bench tools in a small workshop at James Street, Liverpool in 1901. Fig. 3 shows a design for a Formula 1 racing car by the author from the contents of the latest 1979 Meccano Set No. 3. Despite its attractive lines, the basic "½ inch module" form of construction is clearly in evidence, but to-day's modellers are able to "fill-in" their models thanks to thin flexible plates, both in steel and plastics, with which body contours may be readily shaped. Frank Hornby sub-contracted a few of his standard parts to small brass foundries in Liverpool to have his pulleys and flanged wheels cast in brass for subsequent turning in his own workshop. Results proved so crude and unreliable that he made all his own parts after a couple of years and changed over from folded tinplate strips to mild steel strip and provided a burnishing block in the sets of the day to keep the mild steel bright. However, some years before patenting his system under the name "MECCANO" in 1909 he had already gone over to nickel-plating all of his steel parts. Compare the wheels on the 1901 truck to those of the racing car in Fig. 3. This new combination of metal and plastics is illustrated in Fig. 4 where the nine different components for each complete wheel are displayed. Aluminium alloy die-casting is used for the wheel hub which is bolted through the main tyre section on to the 1 in. Bush Wheel with 6 holes. Three additional nuts are shown in Fig. 4 to illustrate the hexagon form adopted for Meccano nuts a few years ago. Older readers of *Model Mechanics* will be more familiar with the square pattern of nuts originally made by Frank Hornby in his own workshop, together with cheese-headed bolts since none were available commercially at the time!). Today Meccano bolts are produced by the million in the Liverpool factory on high-speed thread-rolling machines and are still $\frac{5}{32}$ in. Whitworth thread as in 1901.

Model building in Meccano is reputedly for the age range "Seven to seventy" and adult societies in the U.K. and overseas are still flourishing. The advanced modeller will add tools to his own kit as the complexity of his modelling grows. Only two basic tools, shown in Fig. 5(a) are normally required, but with the adoption of hexagonal nuts by Meccano Ltd., the radio repairer's tools dealing with 4BA electrical nuts (hexagonal) make useful allies for the serious Meccano modeller. In addition, recessed grub screws in the bosses of Meccano gears and the fine terminal screws in Meccano electrical plugs demand the use of a fine bladed screwdriver and Fig. 5(b) shows three tools which are always on the author's modelling bench. There are several other useful aids and these will be dealt with in subsequent articles. The 6BA combination spanner illustrated with ring and open end is readily obtainable at good tool merchants in the U.K. and plastic-handled 4BA box spanners will replace the hexagonal key spanner alongside it. It is most important for the discerning modeller to look after these tools and to make sure that the main screwdriver is a good fit in the slots of the Meccano bolts and that it is *never* given a sharp edge. In fact, the tip of the blade should be "blunt and square" if it is to fit the screw slot properly. This will then ensure that the bolts are not damaged and that fingers and hands are not pierced by lethal weapons!

Probably the greatest appeal in Meccano modelling is that of watching a model in action since we all like "to watch the wheels go round!" and to this end, the range of Meccano gears enables the Formula 1 Racing Car to run smoothly along the floor at the simple end of the model building range, but at the same time they permit the more advanced modeller to construct complex gear boxes which will reproduce planetary motion in working orreries to any degree of accuracy required at laboratory level! A popular sample of Meccano gears is shown in Fig. 6, where gear reductions in the ratios 2:1, 3:1, and 4:1 are illustrated. A very recent introduction by Meccano Ltd. is the plastic gear made on their premises in yellow nylon and seen at (d) in Fig. 6.Plastic gears are not new of course and have been used in industry for

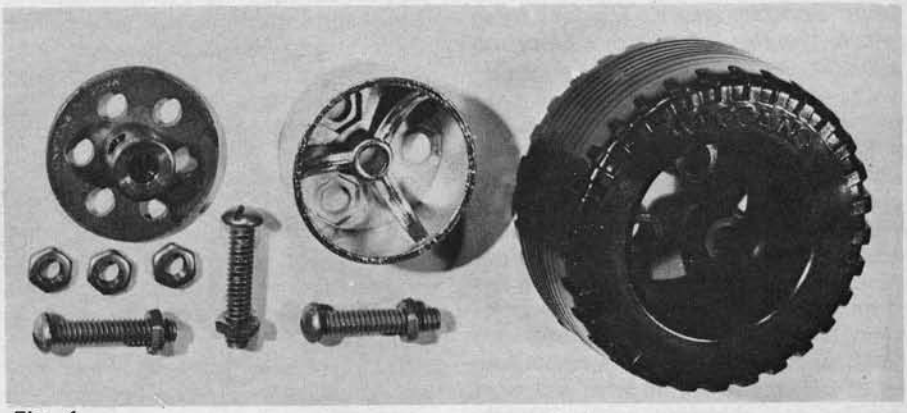


*Fig. 4*
*Component parts of the new Meccano road wheel. Note round-headed screws and hexagon nuts which are standard production for all sizes of Meccano nuts and bolts.*

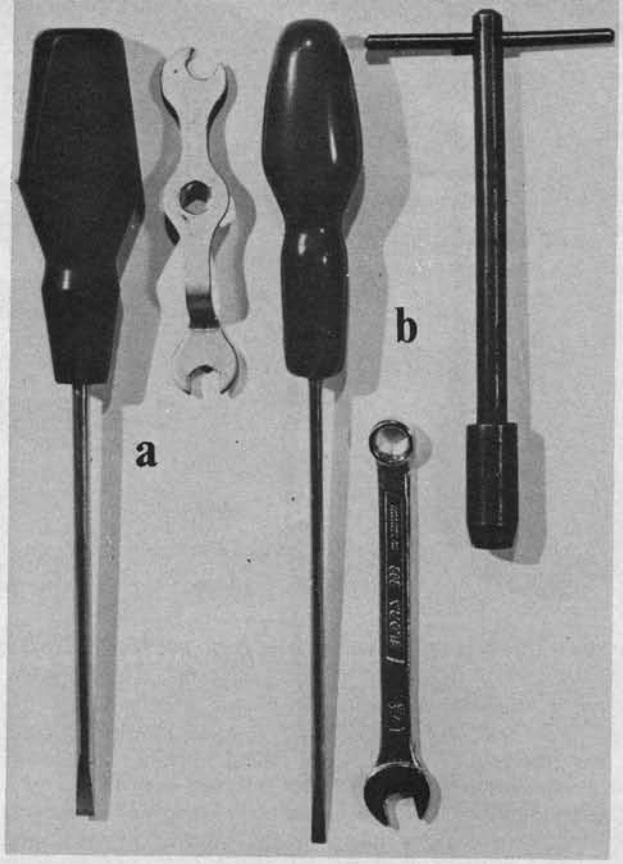



*Fig. 5. Simple tools used in Meccano model building:—*
*(a) The standard Modern Meccano Screwdriver and spanner. Note hexagonal form of the latter. (b) Essential tools in the serious modeller's kit. Top to bottom, thin bladed screwdriver for Grub Screws in recessed holes, 4BA, ring spanner or 4BA hexagonal key spanner.*

many years. Apart from the obvious economy over using non-ferrous metal, the new gears are quiet, resilient and have long-life characteristics. Rather more exotic are the "right-angle drive" gears shown in Fig. 7. Because of the extended manufacturing processes involved, they tend to be more expensive than the simple pinion/gear combinations of Fig. 6, but these gears are generally well made and will last a serious constructor for a life-time. It has been the policy from the earliest times to use engineering terms to describe Meccano components so that the transfer to real-life engineering becomes a natural progression for the real Meccano enthusiast. Each of these special gears have particular functions and these will be outlined in the projects to come in later articles. In some cases, the special gears will only mesh with each other although those illustrated in Fig. 7(h), (i) and (j) are all designed to mesh directly with Meccano Pinions of which there are some eight different types (or sizes) and typical examples of these Pinions are shown in Fig. 6.

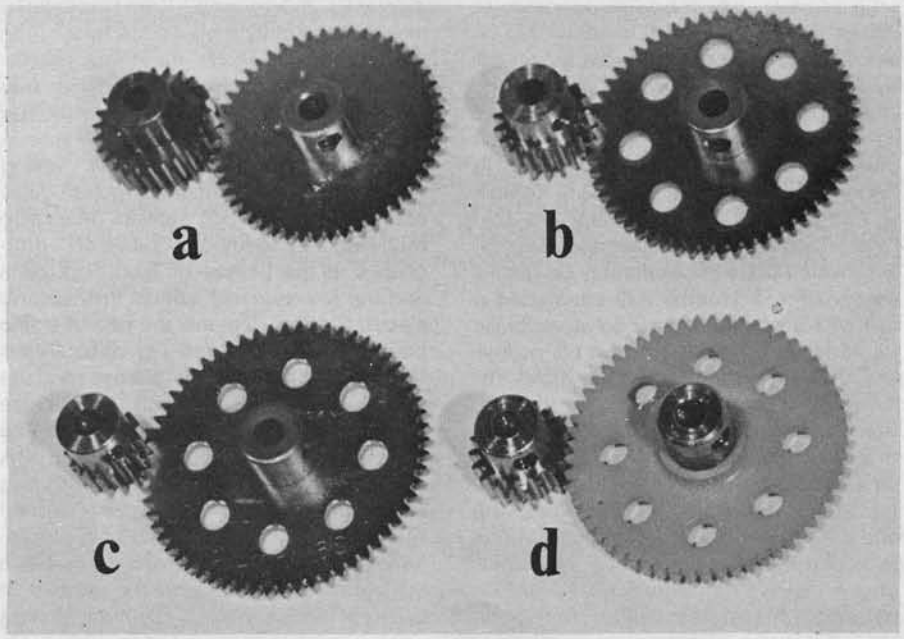



*Fig. 6. A selection of Meccano gears running at standard 1 in. centres spacing. ratios shown are (a) 2:1 (b) 3:1 (c) 4:1. Larger gear at (d) is the latest Meccano product in yellow nylon meshing with the standard ½ in. pinion to give the same drive as in (b).*

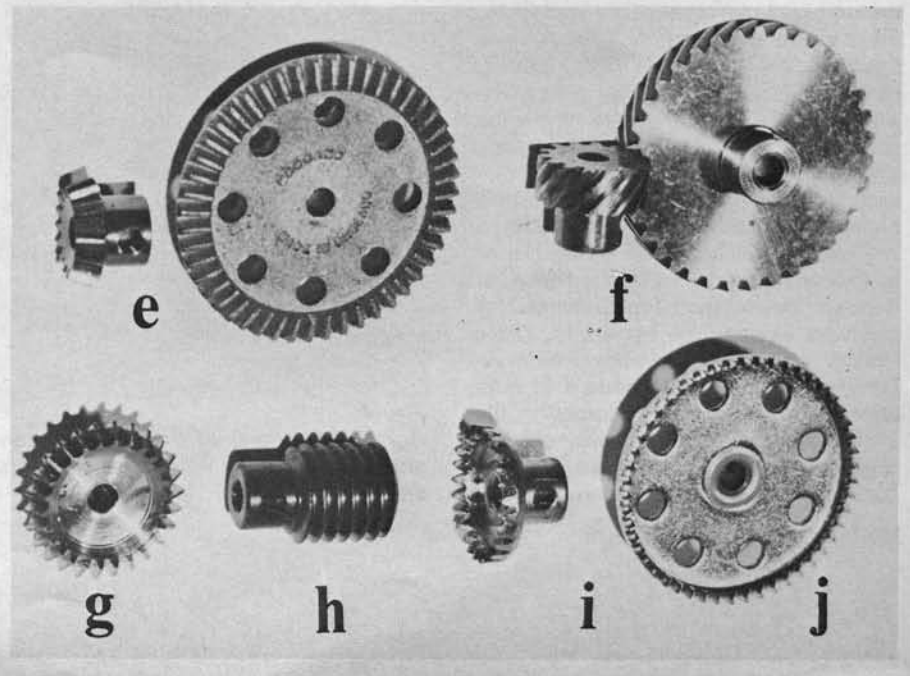



*Fig. 7. Right-angle drive gears from the Meccano range: (e) Bevel gear (f) Helical gears, (g) Standard bevel gear, (h) Worm, (i) and (j) small and large Contrate gears. The last three mesh with standard Meccano pinions.*

From time to time one hears uninformed comment to the effect that modelling in Meccano is tantamount to "Playing with toys!", the inference being that it is no medium for the serious modeller. However, as the author has been involved in Meccano modelling for more than half a century, it is reassuring to know that more and more enthusiasts of all ages are taking up what is a most relaxing and absorbing hobby. Already the reader will have an inkling of the possibilities and potential of the system in this introductory "chat", but the sight of

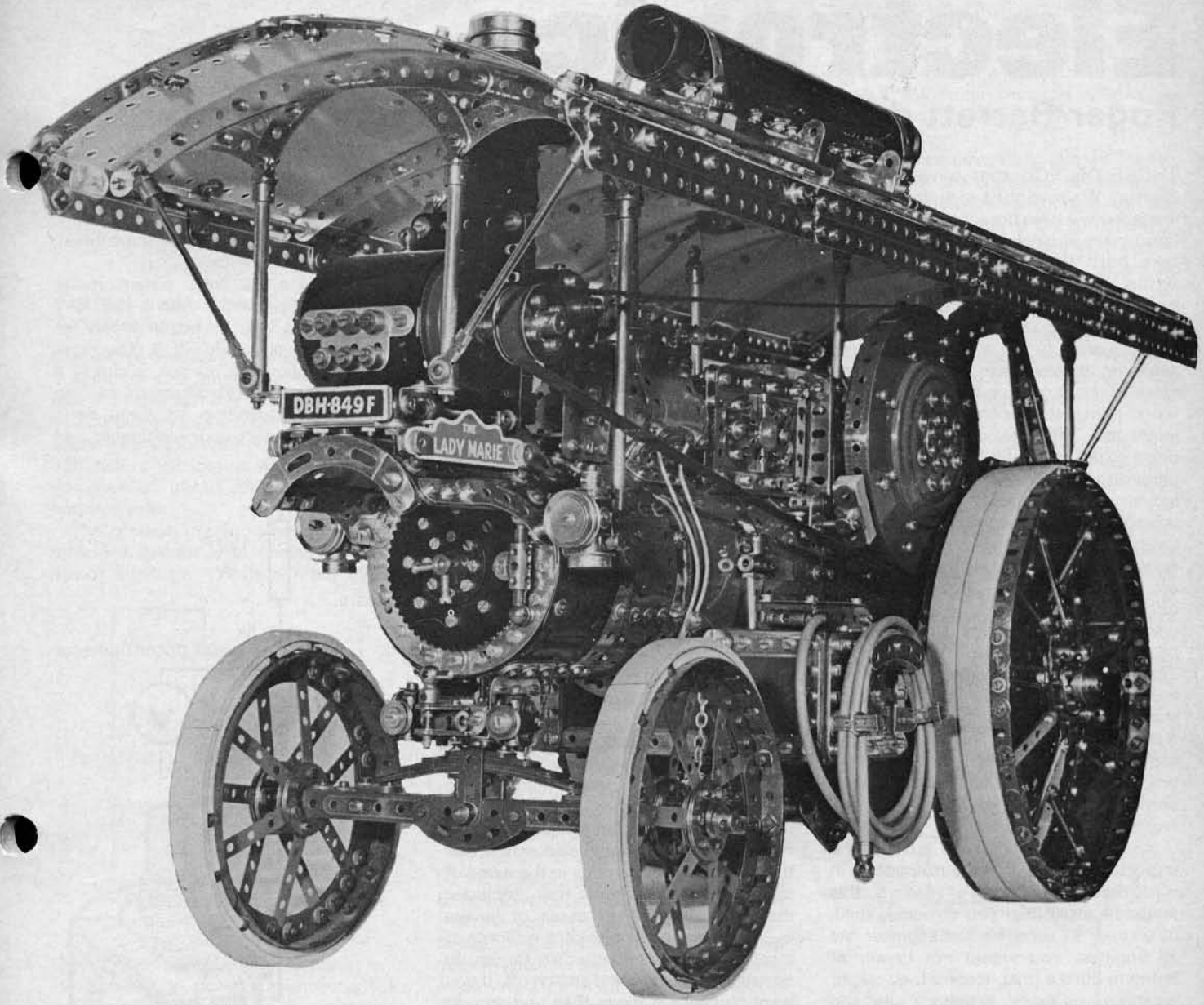



*Fig. 8.*
*An example of fine model building by an advanced constructor. A Scenic Showman's Engine by D. B. Holiday of London. Note the wealth of detail and degree of realism.*

Fig. 8 must surely whet the appetite further. This excellent Showman's Special Scenic Engine is the work of an advanced modeller in London whose daily job has nothing to do with engine building! Apart from a few minor embellishments, the model is built from carefully selected, but standard Meccano parts. Popular as ever, the showgrounds and fairs offer rich material to the modeller in recreating the fascinating engines and mechanisms of the past (although some excellent "futuristic" models appear at the various Meccano shows at home and abroad). Taking advantage of the fact that colour schemes in the system have changed over the years, a tasteful blend of red, green, silver and gold was used in building this superb model and in providing its striking visual appearance. Nor does it just sit in passive form, being fully mechanised with pistons, valve-gear, eccentrics, change-speed gears, differential drive to the road wheels, independent power winch, dynamo drive, brakes and steering — just to mention some of the features! Note the sprung front axle and ornamental lamps, each one built from standard Meccano "brassware". Each wheel is painstakingly built up from individual parts and readers will note the use of "Narrow Strips" (See Fig. 1) in the construction. Generally speaking, the Meccano modeller is not slavishly concerned with "scale", but he is interested in getting general proportions about right when modelling from a prototype and the beauty of the system is that it is all done with a humble screwdriver and spanner! One has to put in a very generous helping of skill, patience and experience when tackling such an advanced model, but the important thing is to appreciate the unlimited versatility of modelling in Meccano. If this opening article encourages some to dust off their sets put away years ago or to encourage others to develop their existing interest and skill in model building then the initial intention will have been achieved.

We shall go on from here to get some simple gearing and chain drives working so that even the novice should be able to grasp essentials of gear ratios and associated mechanisms leading on to further projects of simple, intermediate and more advanced models. Personally, as a life-long devotee, I know of no other hobby which is more absorbing and relaxing and which, because you can take it all to pieces again and is so durable, is one of the cheapest long-term and long-surviving hobbies in existence!

**Next issue Bert Love will continue with a constructional project in Meccano.**

# Electronics

## Roger Barrett describes a few basic components

THOSE OF YOU that have followed George Wainwright's articles in this magazine will have been introduced to the basic ideas of electronics. I would like to take both theory and practice a bit further, but before I do that I would like to go back very briefly to two topics covered by George Wainwright.

First I want to say a few words about soldering in electronic circuits. In any piece of electronic equipment there are more joints than components. These joints are, with few exceptions, made using solder, either by hand or by special soldering machines. The electronics industry therefore relies very heavily on soldered joints and yet the most common cause of equipment failure is, you guessed it, bad solder joints! The point I am trying to make is that you cannot afford to be careless with your soldering, whether you are a raw amateur or a professional computer manufacturer. Either way a dry joint could cost time and money. George Wainwright suggested that you practised using hoops of wire on a piece of Veroboard. This is a very good idea and I would advise you to keep on practising in this way until you are really confident that you have mastered the technique.

Secondly, I want to stress the importance of measurement in electronics. If you are reading this magazine at all then you obviously think of yourself as some kind of engineer. As an engineer you would not dream of trying to build a boat, locomotive, car, or whatever you fancy, without a ruler and possibly much more sophisticated instruments. Now the multimeter discussed last month is like the electronic engineer's ruler, depth gauge and calipers all in one. So, if you want to become any sort of electronic engineer, a meter is a must. You cannot see voltage, current or resistance, so your only contact with these mysterious quantities is via the meter.

Having taken you back a step or two we can now leap forward into the world of semi-conductor devices. I am not intending to leap quite as far as the microprocessors that are always in the headlines these days, but just as far as the basic elements of semi-conductor circuits, that is to say diodes and transistors.

### The Diode

A diode is a two terminal device whose basic property is that it allows current to flow in one direction, but not in the other. The symbol for a diode is shown in Fig. 1 and is almost self-explanatory. We will assume that in any electrical circuit the

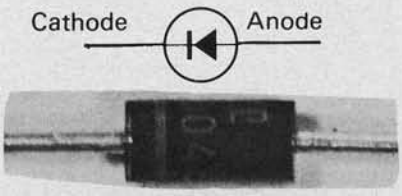



*Fig. 1 Top the diode symbol below a diode shown larger than life. The band always indicates the cathode end.*

current flow is from the positive voltage to the negative (or less positive) voltage. Using this convention we can say that the diode only allows current to flow in the direction of the arrow; that is to say that it will only conduct if the anode is more positive than the cathode. Most diodes nowadays are made from silicon and one of the less desirable properties of silicon diodes is that they will not begin to conduct until the anode is about 0.5 to 0.6 volts positive with respect to the cathode. Once this voltage is exceeded the diode has a very low resistance and the voltage across it will not be more than about 1 volt even at its maximum current.

It is important to bear in mind that a diode, like any other device, can be destroyed if the maximum current rating is exceeded. You should also realise that things happen very quickly in the world of semi-conductors, and that includes destruction, which in cases of severe overload can be complete in a millionth of a second! Hardly enough time for you to realise your mistake and switch off. If you want to check a diode then you can do this quite simply with your multimeter as described last month.

There are many types of diode which are made to have particular properties. Perhaps the best known is the light emitting diode, or LED, which gives out light when it is forward biased, that is when the anode is more positive than the cathode. LED's are now used by the million as indicators and in the familiar red calculator displays. The symbol used for the LED requires no explanation and is shown in Fig. 2.

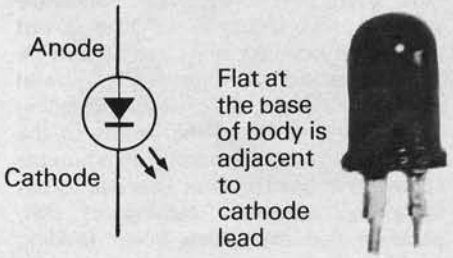



*Fig. 2*
*Symbol for the LED. Actual LED shown larger than life. They come in red, yellow and green.*

Another very common diode is the Zenor diode. If this is tested using a multimeter it appears to be just like any other diode, but the following experiment will show the difference.

First, take a 5kΩ linear potentiometer and connect it in series with a 150Ω ½W resistor across your 8V power supply (or 9V battery) as shown in Fig. 3. The wiper of the potentiometer, or pot, is simply a moving contact which allows us to "tap into" the 5kΩ resistor at any point along its length. Connect your multimeter, set

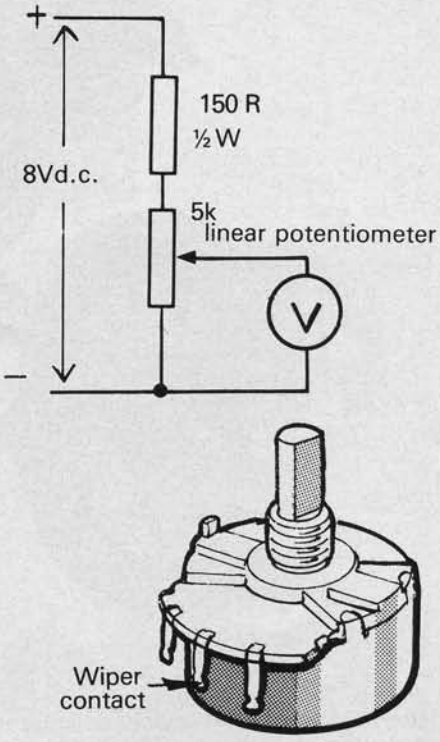
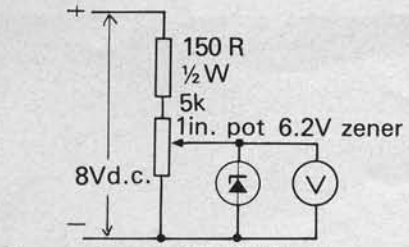



*Fig. 3 Potentiometer as a variable voltage source.*

to a range of 10V or more, between the wiper of the pot and the negative side of the supply as shown. You should find now by turning the pot spindle you can adjust the voltage on the wiper between 0V and about 7.8V for an 8V supply. This is the simplest variable voltage supply.

Now connect a 6.2V zener diode between the wiper of the pot and the negative side of the supply, as shown in Fig. 4. Notice that the cathode of the zener is made more positive than the anode, that is the diode is reverse biased. You should now find that with the supply at 8V (or 9V) as before, the meter reading will only go up to 6.2V where it will stop. Any further movement of the pot should not cause any noticeable change in the reading.

I said that a diode does not conduct in




Zener diode is 6.2V 400mW
Suitable types are
BZY88 C6V2
BZY79 C6V2 ZF6.2

*Fig. 4 Variable voltage source with Zener limiting.*

the reverse direction and this is true up to a point for the zener. The difference is that the zener is made in such a way that at a certain reverse voltage it will conduct easily. This voltage for our device is 6.2V, but zeners are made with breakdown voltages of about 2V up to several hundred volts.

The obvious use for zener, or voltage reference, diodes is in constant voltage power supplies. The integrated circuit

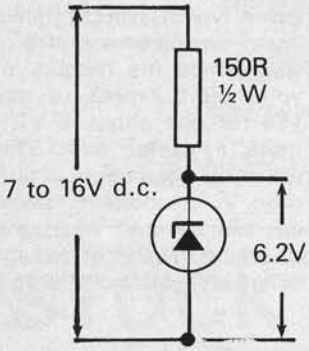



*Fig 5 Simple Voltage Regulator*

used in George Wainwright's power unit includes such a voltage reference diode.

The simplest form of zener regulator is shown in Fig. 5. This will give an output of 6.2V for an input between about 7V and 16V. Although this is a useful circuit there is a limit to how much current we can draw from it. This is easily shown by connecting an 82Ω resistor across the output and measuring the voltage. You will find that instead of 6.2V the voltage will now be about 2.8V. So much for our constant voltage! What we need is an amplifier on the output to increase the amount of current available, and the simplest type of amplifier for this job is a transistor.

**The Transistor**

The name transistor is one which is used for several different semi-conductor devices, but the one that we will be talking about is the bipolar junction transistor. This is rather a mouthful so in general it is assumed that a "transistor" is a bipolar etc., etc. and only the less common ones are named in full.

The symbol used for a transistor is shown in Fig. 6. I should say are shown because you will see that there are in fact

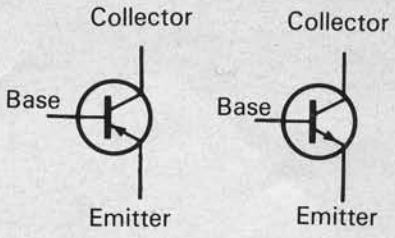
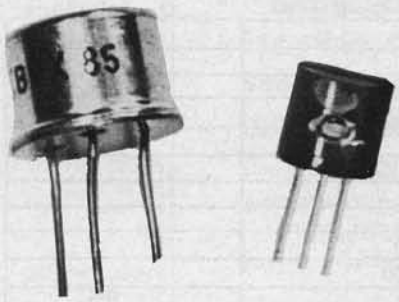



*Fig 6 Transistor*

two symbols. The transistors represented by them are only different in their polarity; that is to say the PNP type is used with its base and collector negative with respect to the emitter, while the NPN type has its base and collector positive. The direction of current flow, as for the diode, is in the direction of the arrow.

The main current flow in the transistor is between the collector and the emitter, and the base is used to control this current. In a perfect transistor the collector current is simply given by the base current multiplied by a quantity known as the gain of the transistor, which I shall call ß (beta). Modern silicon transistors have gain values between 20, for a high current type, and 1000 for low current ones. A good average value is about 100. This means for example that if we want a current of 100mA (0.1A) to flow betwen the collector and the emitter, we need only supply a current of 1mA into the base. The gain can be measured quite easily using the circuit shown in Fig. 7.

In this circuit the base current is fixed by the resistor, which is 68k ohm. Using Ohm's Law (from last month) we know that the current is given by the voltage divided by the resistance. Now, the base-emitter junction is a silicon diode and to make any current flow we need about 0.6V. This leaves 7.4V across the resistor so the current will be 7.4/68,000 = 0.000109 amps = 0.109 milliamps (mA). To measure the gain we just need to measure the collector current in mA and divide this by 0.109, or for a rough and ready measurement, just multiply it by 10. For example, if the collector current is 9.3 mA, the gain is 9.3/0.109 = 85.3, or using the approximate method, about 93.

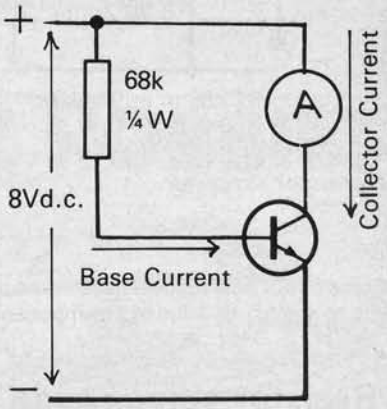


*Two types of transistor, on the left metal cased type To5, the right one is cased in plastic.*

This current flows into the collector, but you may wonder where it comes out. The answer of course is that it all comes out of the emitter, and if you connect the meter in the emitter circuit as in Fig. 8 the current reading should be almost the same as before.

There is one other thing that we need to know about the transistor at this stage and that is that the voltage between the base and the emitter is 0.5 to 0.7 volts, and the transistor will always try to keep it that way. It achieves this by passing as much current as the circuit resistances requires to make the voltage right. I hope this will be a bit more clear later on, but the thing to remember is that if the circuit resistances are too low, the transistor will try to pass a very high current which may destroy it.

Enough of this scaremongering, and back to the amplifier for our constant voltage supply. For this, the transistor is simply connected to the output of the previous circuit (Fig. 5) as shown in Fig. 9. Remember that the emitter will be 0.6V below the base and that the emitter current is ß times the base current. I said before that the simple circuit could give about 10mA, and this can now go into the transistor base. The transistor will then provide, for an average device, a




Suitable transistor types
BFX85, BFY50, BFY52

*Fig 7 Measurement of Collector Current*

maximum of 500mA which is enough to run a lamp, small motor, radio etc. In practice, if the current is more than about 300mA the transistor will get rather hot and could be damaged.

The current does, of course, depend on the resistance which is connected across the output. If you repeat the test that I suggested for the simple circuit and connect an 82Ω resistor across the output, the current can be calculated to be 5.6 volts 82Ω = 0.0683 amps. This is the current that the transistor must supply to keep the emitter at 5.6V.

As the resistance across the output is reduced, the transistor must supply more current to keep the emitter voltage 5.6V. This current flowing through the transistor generates heat, and at a current of 300mA with an 8V supply, the transistor will be near its maximum

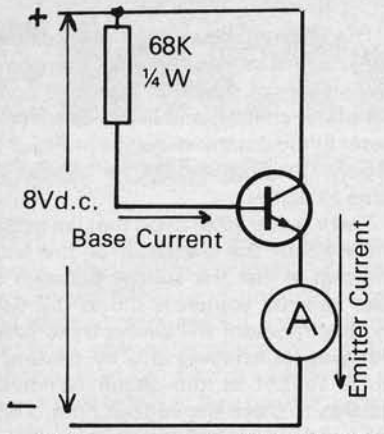



*Fig 8 Measurement of Emitter Current*

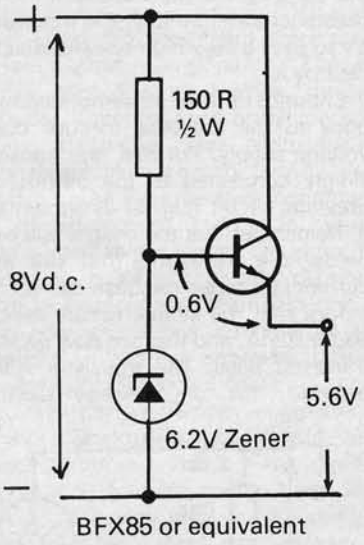



*Fig 9 Voltage Regulator with Transistor Amplifier*

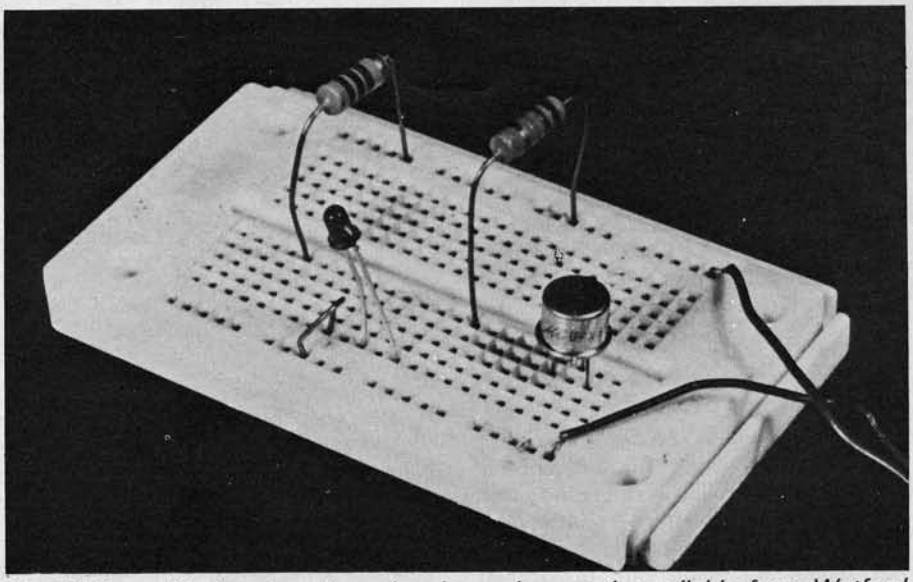


*Fig 10 The solderless breadboard, a low price one is available from Watford electronics.*

allowed temperature. As long as you keep below this limit, you should find the circuit gives a constant voltage with no problems.

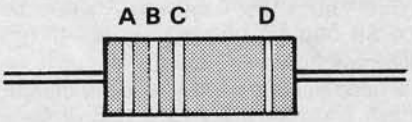
To change the subject a bit, you may want to try some of these simple circuits and wonder how to actually go about it. One way is to simply twist the component leads together, but this is obviously not at all satisfactory. Another way is to solder the component to a piece of Veroboard, but this is rather slow and a bit too permanent for experimental circuits.

The modern answer to this problem is the solderless breadboard. This is no more than an array of tiny sockets which the component leads can be plugged into. The individual sockets are interconnected in groups of about five and it is normal for the top and bottom rows to be interconnected. A typical layout is shown in Fig. 10. Prices depend on the area of the board and hence the number of contacts; you might expect to pay between £3-£5 for one about 4" × 2", which is quite a useful size. This investment will give a good return in time saved and also in components saved because these can be used again and again without risking the sort of damage that can be done by repeated soldering.

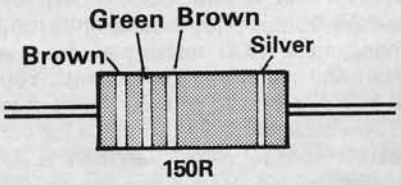
Some of our new readers have asked me to publish the colour codings for resistors. You will find it will soon become second nature to you to identify th value of a component, but at first, do double-check with the chart below. (Ed)

## Resistor colour code

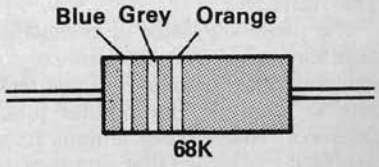
**R = ohms**
**K = Kilo ohms**
**V = Volts**




**Examples that occur in the above article.**




| | A and B | C = X | D = Tolerance |
|---|---|---|---|
| Black | 0 | | |
| Brown | 1 | 0 | 1% |
| Red | 2 | 00 | 2% |
| Orange | 3 | 000 | |
| Yellow | 4 | 0000 | |
| Green | 5 | 00000 | |
| Blue | 6 | 000000 | |
| Violet | 7 | 0000000 | |
| Grey | 8 | 00000000 | |
| White | 9 | 000000000 | |
| Gold | | | 5% |
| Silver | | | 10% |
| No band of colour at D | | | 20% |




**4.7K would be described 4K7**

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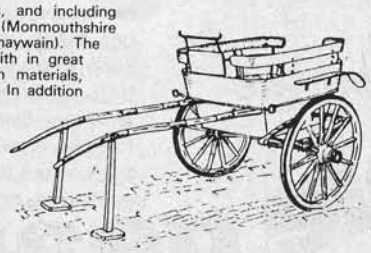

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# Cutting simple gears

by Rex Tingey

by Rex Tingey

**Rex Tingey, who has reviewed the Unimat lathes for us, shows how to cut gears on these machines.**

When a spur gear wheel is made to be run with another spur gear wheel the teeth should have a particular shape so that they will mesh together well, run together with the touching areas rolling rather than rubbing, one on the other, and present the maximum touching areas possible yet still escape easily. Straight teeth, hard to mesh, will lock together, and when the mesh is loosened, to enable the teeth to escape, the teeth rub along the length of the teeth on the other wheel giving frictional loss of power. In practice a modulated straight-sided tooth form is used which has its upper half angled and made rounded. This tooth form is relatively easy to generate in straight-across spur gears with the correct form of cutter.

Among the items listed as accessories for both the Unimat 3 and the Unimat SL are gear-cutting mills, which are specially shaped side-milling wheels. These gear-milling cutters cut a gap, not a tooth, and leave the sides of the gap correctly made to form a gear tooth when the next gap is cut; the indexing attachment is used to position each cut correctly. This system limits the usefulness of each modular cutter to a certain size of tooth and to small variations in gearwheel diameter. Six of these cutting wheels are required to cover the range at a cost of over £100 — plus the cost of the arbor!

A cheaper, and more extensive method of cutting gears is to use the divisions provided by the indexing attachment, but with home-made tooth-cutting tools. The cutter takes the form of a multi-toothed hob, quite easily made on the Unimat lathe, which not only cuts a straight sided gap into the gear wheel blank but simultaneously modifies the tooth shape being formed either side of the gap.

This means that the cutting hob can be straight sided with no fancy cutting pattern built in, it can deal with any diameter of blank, from large down to small, and a number of hobs can be made to give large or small tooth sizes which will run together well with other teeth of the same size which have been cut with the same hob. The hobs can be made on any other lathe, of course, and used on any milling and drilling assembly with an indexing unit.

The hobs are made from round silver steel turned on the lathe, then cutting teeth are formed using the indexing attachment and a grinding wheel in the vertical mode. Silver steel contains no silver and is quite inexpensive. It is a steel which contains sufficient carbon to make it suitable for hardening and tempering, particularly for tool-making. It is produced in a range of sizes to very fine tolerances, and is easy to machine. The hardening and tempering part is not difficult and can be carried out using a small blowlamp or even just a gas-ring. Most tool merchants sell lengths of silver steel, as do many of the advertisers in this magazine.

### Making the Hobs

See Fig 1 stages in making hobs.

First cut a length of silver steel, five times the overall tooth size plus $\frac{1}{8}$ in. for the Allen grub screw, so for the eight teeth per inch hob cut a ¾ in. length. Face both ends in the 3-jaw chuck, drill with a No. 3 centre drill as far as the flutes allow and then drill right through with a ¼ in. drill. Drill No. 32 for the grub screw and tap 4 BA. Run a ¼ in. reamer through the bore, fit a $\frac{1}{8}$ in. long 4 BA grub screw and secure the blank to a piece of ¼ in. silver steel rod for turning between centres.

Take a light cut from the surface to ensure concentricity, then turn the securing screw end down below the tooth level. With the 40 deg. tool make four shallow cuts to be between the teeth. to measure these the handwheel divisions can be used, fifty divisions equalling $\frac{1}{10}$ in., but check with a rule before continuing; keep the appropriate BSF or Whitworth bolt handy as a quick check whilst working. Cut the two grooves, from left to right, either side of the central tooth, to the correct depth, using the geometry as explained, and a depth gauge. The width of the bottom of the cut can be regulated with the handwheel divisions. Cut the other two grooves to form the five matching teeth, and finish by cutting the two outer surfaces to a 20 deg. angle.

To make the teeth into cutters set the work on the ¼ in. mandrel in the 3-jaw chuck, on the indexing head with the 36 division wheel in place, and lock the head onto the cross-slide. Use the Woodruffe cutter to make six slots across the grooves, at six division intervals, taking the slots down to just below the teeth. But feed in no more than five or six handwheel divisions at a time before running the cross-slide across; a greater feed causes overheating and soon blunts the cutter. Replace the Woodruffe cutter with a disc grinding wheel, set the dividing head three teeth back and grind off about two-thirds of tooth area. Set the

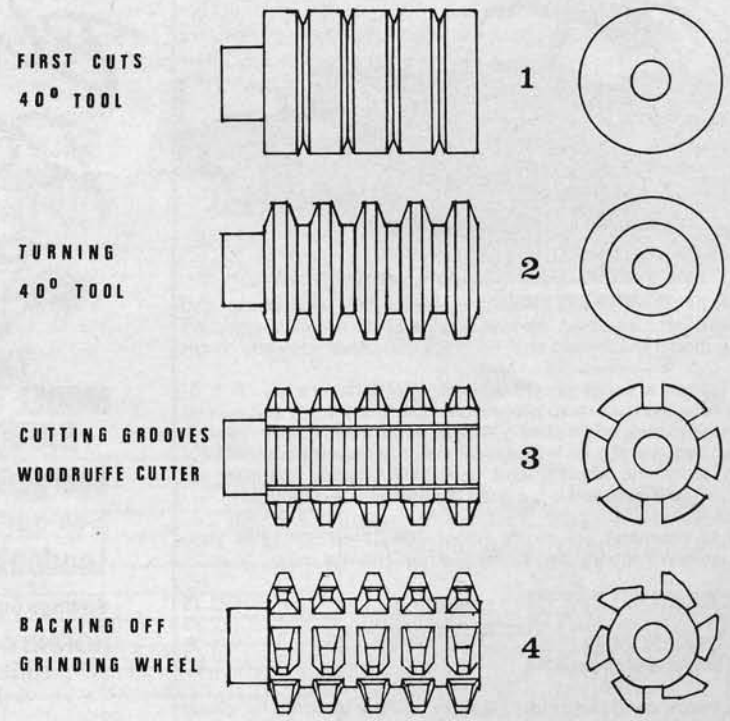



*Fig 1 Stages in making Hobs*

head two more teeth back and back off finely almost to the cutting edge, all six slots. Clean off all traces of grinding from the lathe, dismantling if necessary.

### Hardening and Tempering

Remove the set screw and push the hob onto a piece of copper pipe, ⅜in. O.D., whose end has been cut and squeezed together, and place on a hearth. Have a pair of old pliers and a can of cold water handy. With the blowtorch heat up the hob to cherry red, pick up the copper pipe with the pliers keeping the pipe upright with the hob at the top, and give a final blow to ensure even redness, then dunk it in the water. Include the copper pipe in the dunking or you will get a surprise when you pick it up again. Take the hob from the water and replace the water with cold. With a good file vigorously attack the flat-bottomed grooves, where it should do little but remove a little blackening. With emery cloth clean the ends, including the extra surface for the set screw, and push the other end back onto the copper pipe to reheat. This time hold the pipe with the pliers and heat the copper, only, until the cleaned parts of the hob go to a nice yellow, as if the hob had been varnished, and then dunk in the water. The hob is now finished, there is no need to clean off, and you will have burnt off the burrs with the first blow.

### Hobs

To avoid complications this system of spur gear cutting uses teeth per inch (TPI) for measurements of gear-wheels, which means that the old-fashioned Whitworth and B.S.F. screw-threads can be brought in as a cutting guide when making hobs on the lathe. The disadvantage of using teeth per inch is that the gear wheels end up with odd sized diameters, due to π, however, the modern calculator can be brought into use to assist the drawing-up of tables. The tables show the diameter of blank required for a particular number of teeth, and the working radius of the finished gear wheel for various tpi sizes, covering the range of indexing possibilities of the Unimats.

**Table to show diameter of blank**

| No of Teeth | Diameter of Blank | | | | | | | | ½ × D.P. of Gear Wheel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | y = 1.374x | | | | y = 1.5x | | | | | | | |
| 5 | .238 | .228 | .19 | .143 | .293 | .234 | .195 | .147 | .1 | .08 | .066 | .05 |
| 6 | .325 | .26 | .217 | .163 | .333 | .266 | .222 | .167 | .12 | .096 | .08 | .06 |
| 8 | .405 | .323 | .27 | .202 | .412 | .33 | .275 | .206 | .16 | .138 | .106 | .08 |
| 9 | .444 | .335 | .296 | .222 | .452 | .362 | .301 | .226 | .18 | .145 | .119 | .09 |
| 10 | .484 | .387 | .323 | .242 | .492 | .394 | .328 | .246 | .199 | .16 | .133 | .1 |
| 12 | .564 | .45 | .376 | .282 | .572 | .457 | .381 | .286 | .239 | .19 | .159 | .12 |
| 15 | .683 | .546 | .455 | .342 | .69 | .553 | .46 | .346 | .299 | .24 | .199 | .15 |
| 16 | .723 | .578 | .48 | .362 | .73 | .585 | .487 | .366 | .319 | .255 | .212 | .16 |
| 18 | .80 | .642 | .535 | .401 | .81 | .648 | .54 | .405 | .358 | .286 | .239 | .18 |
| 20 | .882 | .705 | .588 | .441 | .89 | .712 | .593 | .445 | .398 | .318 | .265 | .199 |
| 24 | 1.04 | .833 | .694 | .52 | 1.05 | .839 | .70 | .525 | .478 | .382 | .318 | .24 |
| 30 | 1.28 | 1.02 | .853 | .64 | 1.29 | 1.03 | .859 | .644 | .597 | .477 | .398 | .299 |
| 36 | 1.52 | 1.21 | 1.02 | .76 | 1.53 | 1.22 | 1.02 | .763 | .716 | .573 | .478 | .36 |
| 40 | 1.68 | 1.35 | 1.12 | .84 | 1.69 | 1.35 | 1.13 | .843 | .796 | .636 | .53 | .398 |
| 48 | 2.0 | 1.6 | 1.33 | 1.0 | 2.01 | 1.6 | 1.34 | 1.0 | .955 | .764 | .636 | .477 |
| 60 | 2.47 | 1.98 | 1.65 | 1.24 | 2.40 | 1.99 | 1.66 | 1.24 | 1.19 | .955 | .795 | .596 |
| 72 | 2.95 | 2.36 | 1.97 | 1.48 | 2.96 | 2.37 | 1.98 | 1.48 | 1.43 | 1.15 | .955 | .716 |
| 80 | 3.27 | 2.62 | 2.18 | 1.64 | 3.28 | 2.62 | 2.19 | 1.64 | 1.59 | 1.27 | 1.06 | .795 |
| 96 | 3.9 | 3.13 | 2.6 | 1.95 | 3.92 | 3.13 | 2.69 | 1.96 | 1.9 | 1.53 | 1.27 | .955 |
| | 8 | 10 | 12 | 16 | 8 | 10 | 12 | 16 | 8 | 10 | 12 | 16 |
| | Teeth per inch | | | | | | | | | | | |

The geometry of the hob is shown in the diagram: x is a distance halfway down the tooth, if there are ten teeth to the inch then x = .05in. If a = b = c = d, then y = 1.374x; this gives a standard short tooth; y can be increased to 1.5x to give a slightly longer tooth and allow the hob to wear and be sharpened, figures for both are tabled to the equation:

$$\frac{\text{number of teeth required}}{\text{teeth per inch}} + (2 \times \tfrac{1}{2}y) = \frac{\text{Teeth per inch} \times \pi}{\text{diameter of blank}}$$

The length of the bottom of the groove between the teeth when y = 1.374x is b + c = ½y, but when y = 1.5x the bottom of the groove becomes .454x. The hobs have a central cutter, cutting a space, with two cutters either side modifying the forming teeth either side, mainly above x, dependent on the curve of the blank. If a tooth were to be cut instead of a space the outer edges of the two cutters would not be radial and would cut under the x line and produce a hollow tooth, and the form of tooth cut would vary considerably from large to small gears.

The four hobs which I made correspond to 1in., ¾in., and ½in. Whitworth, and to ½in. BSF. These give the selection of eight, ten, twelve and sixteen teeth per inch. The hobs are made from ¾in. diameter silver steel, bored ¼in. and secured to a ¼in. axle for both making and using them, with a 4 BA Allen grub screw. A lathe tool is required to cut the 40 deg. angle (20 deg. either side), and this is best made from a ¼in. square HSS

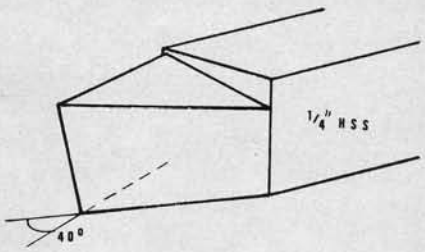



*Fig 3 lathe tool for making Hobs*

tool blank, using a grinding wheel, and a protractor set to the required angle. The tool should have an angle of 40 deg. between its two faces, which are backed off on the downward direction. The top surface is relieved back and to the left; the tool is pointed but the cut made flat-bottomed. When used the tool is fed in to match the left side of the cut, advanced, and a further cut made.

Other tools needed for making the hobs are a ⅛in. × ½in. Woodruffe cutter for the grooving, and a disc grinding wheel for backing off the cutting teeth of the hobs. You will also require a simple depth gauge, which I will describe later.

### Making Gearwheels

To make a gearwheel first cut the blank with a diameter a little larger than the finished diameter. Use the table to find the size of blank neded for the size and number of teeth. The effective radius of the gear is given in the last part of the table; this is the radius which can be used to draw a circle touching another circle to

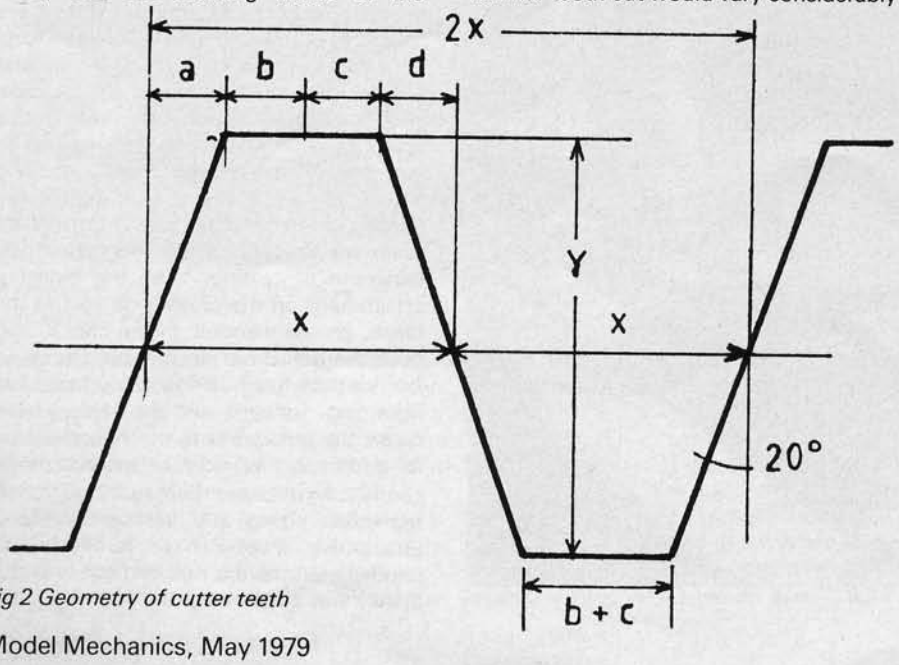
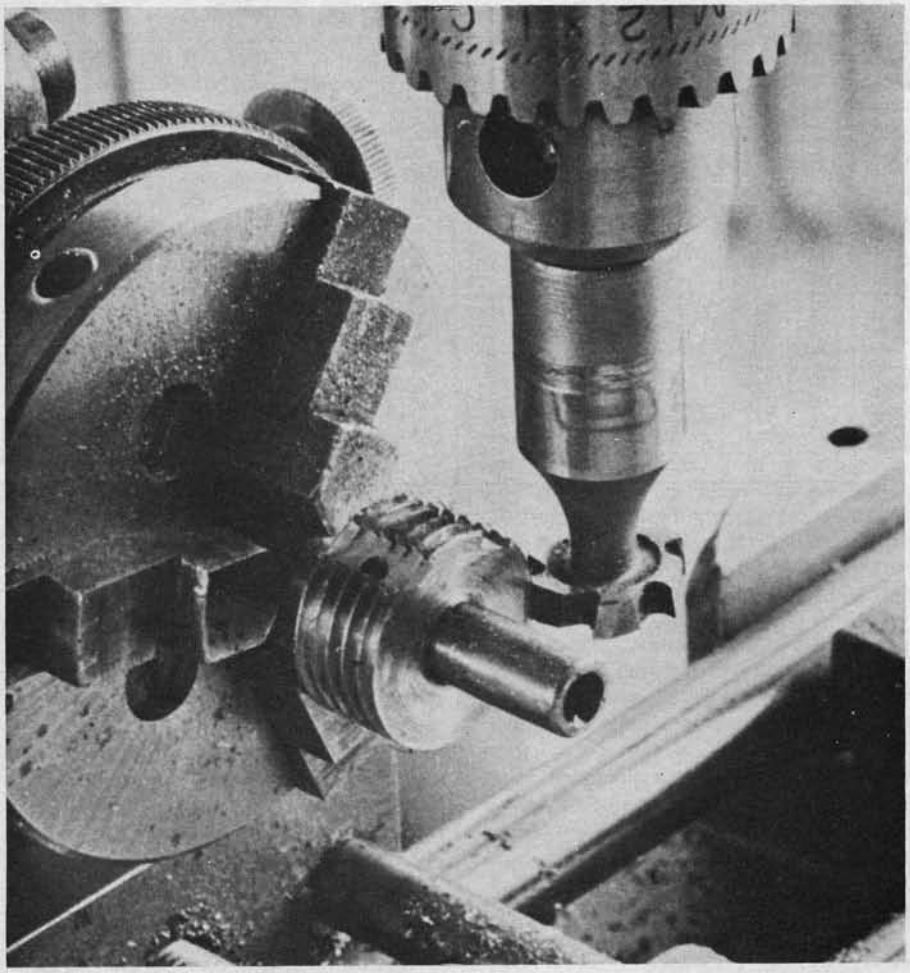
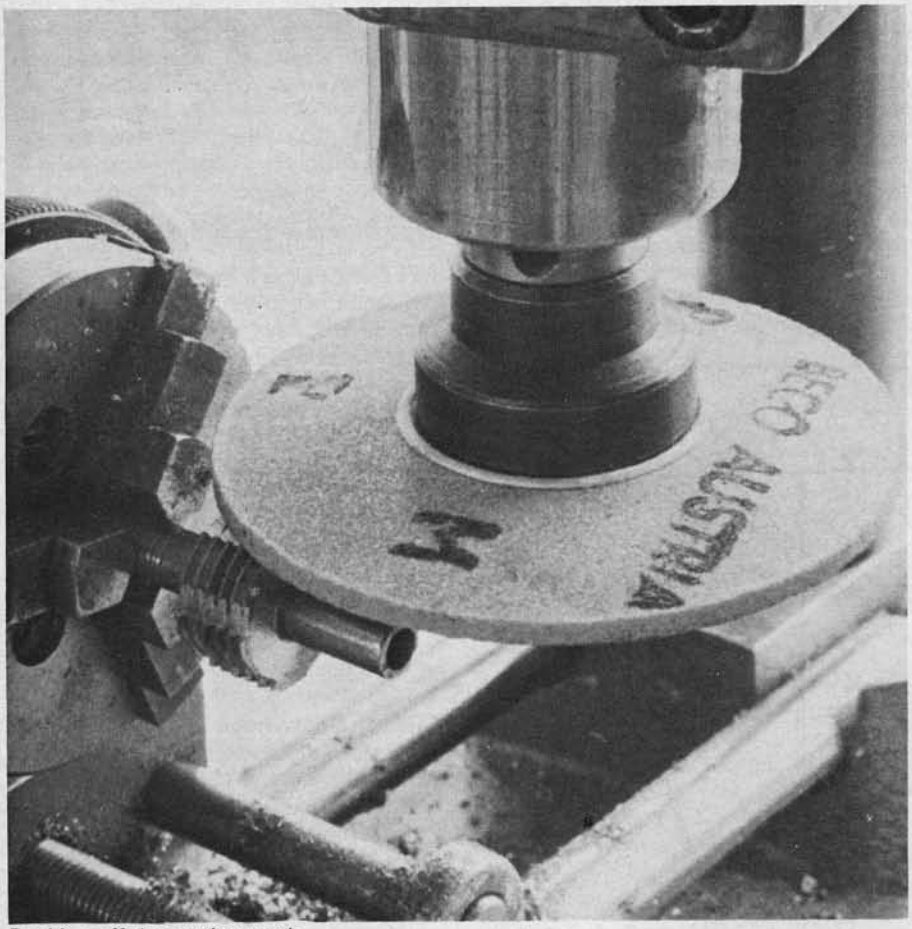


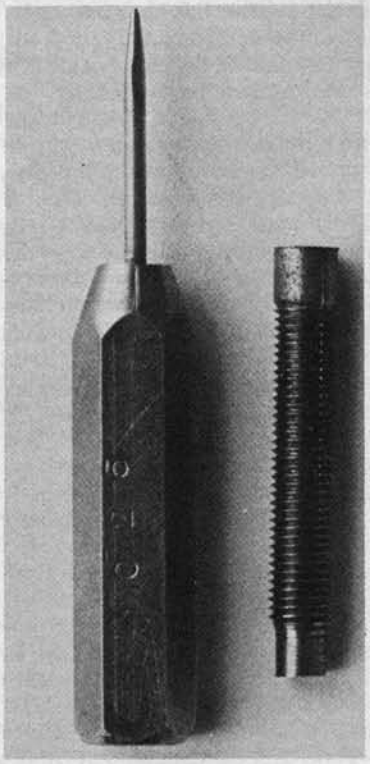

*Fig 2 Geometry of cutter teeth*



*Grooving the turned silver steel hob using a Woodruffe cutter*



*Backing off the cutting teeth*



*The depth gauge will be described in detail in Part II*

represent two gears in mesh without worrying about the teeth. It can be used for positioning the centres of gearwheels to be run together.

Take the blank and rub down one side flat on emery cloth on a flat surface, to remove sawcuts. Chuck the blank, finished side in, in the 3-jaw and turn to a finish as much of the surface as the jaws will allow; enough of the centre of the blank needs finishing to take the mandrel, the rest can be finished on the mandrel.

Centre-drill right through, following with a drill the diameter of the mandrel. Fit the blank to the mandrel and secure to finish the front surface and to turn down the diameter to the blank size, checking with a vernier caliper.

Select the correct dividing wheel for the indexing attachment; the Unimats have four sizes of dividing wheel, 30, 36, 40 and 48 teeth for the S.L., and 24, 30, 36 and 40 divisions for the Unimat 3, the table shows the possibilities with these plates up to 36 teeth. Using this hob method to cut, say, 60 teeth with the 30 dividing wheel, you will find that after cutting the spaced 30 teeth that the intermediate teeth are almost finished and require the minimum of cutting. With the indexing attachment on the cross-slide secure the blank, on the mandrel, in the chuck, and have the hob driven in the drill chuck on the vertical head. Bring the cross-slide right over, forward, and the vertical head down the column until the hob presents its middle cutting row to the horizontal centre of the blank; finalise by adjusting the quill, using the vertical fine-feed attachment if you have it. Turn the handwheel until the hob can cut into the blank, and cut through by means of the