TORPEDOES IN NAVAL WARFARE

NEWNES

PRACTICAL MECHANICS

MARCH 1940

PRICE IN AUSTRALIA & NEW ZEALAND 6d.

SUBSCRIPTION RATES
Inland and Abroad 8s. 6d. per annum.
Canada - - 8s. per annum.
Editorial and Advertisement Office: "Practical Mechanics," George Newnes Ltd.
Tower House, Southampton Street, Strand, W.C.2.
'Phone: Temple Bar 4363.
Telegrams: Newnes, Rand, London.
Registered at the G.P.O. for transmission by Canadian Magazine Post.

PRACTICAL MECHANICS

Editor: F. J. CAMM

VOL. VII. MARCH, 1940. No. 78

THE INVENTED NEED

By the Editor

IN walking through one of our large London stores the other day, I reflected upon the enormous number of gadgets—a word I use for want of a better term, gadgets being something you don't want, but must have!—which have been produced on the assumption that people would invent an excuse to use them. The successful inventor is one who caters for an existing need, whereas most of our unsuccessful inventors are those who first invent the need and then produce an invention for the invented need.

Most people possess a large number of gadgets presented to them on special occasions, such as birthdays or at Christmas, which have cost, *in toto*, quite a large sum of money, but which have merely given them temporary pleasure at the time the gifts were made. Thus, these expensive gadgets are no more than toys which amuse for a short time. They are placed by in drawers and seldom looked at again.

Multiple Gadgets

ONE of the most popular lines for the inventor is to produce one gadget which does the work of six. I cannot think of any successful multiple gadget or tool. Thus we have lighters which combine a watch, a nail file, a pocket knife, a pair of scissors, and a pencil and a rule. In order to produce the completed design to a size which will make it fit the vest pocket, not one part of the gadget is really satisfactory. Incidentally, why do inventors like to make things specially for the vest pocket? The number of devices, as well as books, which I possess which have been specially designed to fit the vest pocket would fill a van. It is time that inventors remembered that the vest pocket is already overloaded and cannot carry further devices.

In engineering there is a very large number of combination tools. You do not see a skilled engineer using them, however. They fail in one or more important directions. You remember the watches which were sold some years ago whose dials included a number of smaller dials telling the time in most of the important cities of the world. They failed commercially because they catered for a need which did not exist.

Era of Cases

THIS is also the era of cases. Directly something is produced, someone else wishes to sell a case for it. There are fancy wallets with divisions marked stamps, treasury note, driving licence, insurance certificate, registration card, etc. There are cases marked pyjamas and brushes and collars and ties. Apparently, the producers of these gadgets have not a high opinion of public intelligence, for they presume that we need to be told that a collar box has collars in it.

One of the queries I sometimes receive concerns a list of things to invent. There is no limit to the number of things still required, and my advice to the budding inventor is not to waste his time inventing a need, but to produce inventions which are needed. Needle threaders exist by the thousand, and they will never be successful. Patent alarm clocks which wake you up after they have boiled the water, made the tea, cooked the breakfast eggs, and operated the vacuum cleaner have also been produced in large numbers, but none of them have succeeded commercially. Similarly, time-control switches which switch on the radio at a predetermined hour and switch off again are also failures. Inventors should remember that the human race has not yet reached that stage where it is too tired to move.

"Practical Engineering"

MY new journal, *Practical Engineering*, six issues of which have now been published, has been well received by engineers and the engineering trade. I have had a large number of most encouraging letters from principals, works managers, designers, draughtsmen, tool-makers, turners, fitters, gauge makers, metallurgists, foundrymen, millers, in fact, from the whole range of engineering professions.

Practical Engineering is the modern engineering weekly dealing with all of the latest processes employed in engineering. It is, indeed, a journal without a competitor, and its success confirms the view I took when the idea was first projected, namely, that such a journal had been needed for years.

If you have not already sampled a copy, I shall be glad if you will do me the favour of asking your newsagent to show you one. *Practical Engineering* is published every Thursday at 4d.

Practical Engineering is entirely modern in its selection of subjects, for it deals week by week with every workshop process. The leading authorities on special subjects have been retained to contribute exclusive articles, such as die-casting, plastics, centrifugal casting, drawing office practice, press tool design, time-saving methods, finishing processes, heat treatment of metals, test equipment, inspection, and, in fact, with every sub-division on the mechanical engineering industry.

In connection with it there is a special offer of "The Engineers Handbook," which is an extremely useful compilation of facts, tables, data and formula needed by all those engaged in engineering. The book extends to 256 pages and is handsomely bound. It is a volume which in the ordinary way would cost half a guinea

Torpedoes in

An Insight into the History, Mechanics


Working on the stern section of a torpedo

There are more than 6000 separate parts in every torpedo, and it takes several months to make one. Before being sent out to His Majesty's ships every torpedo has to be tried out and passed under working conditions

THE word "torpedo" comes from the Latin, *torpere*, meaning, "to be rigid," the term being originally applied to denote a certain family of electrical fishes of the ray or skate variety. Exactly how the term originally became used to denote a submarine weapon of aggression is difficult to ascertain. All we know is that the notion of the explosive torpedo arose during the time of the American Civil War in the sixties of the last century, at which period certain very primitive types of underwater explosive bombs were employed by one or other of the American belligerents, these explosive devices consisting of a light steel canister provided with a percussion cap and filled with a small quantity of high explosive. This canister was secured to the end of a very long rod which latter was attached to a small boat which was cautiously steered towards the ship to be attacked. Frequently much damage was effected by this crude method of marine attack, but often enough the attacking vessel was blown to pieces along with the attacked one. Hence this mode of marine warfare was relinquished, although there were many in America who retained the idea that it might be possible to devise a small vessel filled with explosives which would be capable of travelling of its own accord and steering itself through the waves until it came into explosive impact with the object of its attack.

Whitehead's Torpedo

The first individual to make practicable the torpedo was an Englishman named Whitehead, who was, towards the end of the sixties of the last century, in charge of an engineering company in Fiume, which was then an Austrian seaport.

A certain individual named Luppis had for some time been working on a torpedo device which was driven by a clockwork motor, and which was steered by ropes stretched through the waters. Luppis's invention was obviously impracticable, and the Austrian naval authorities in no mean terms informed him of that fact. Discouraged, Luppis, seems to have climbed out of the picture, for we hear nothing more about him.

Whitehead, however, who knew Luppis and, also, the details of his invention, found a peculiar fascination and satisfaction in working upon the details of a torpedo which would travel under water and steer itself. He put in a couple of years of hard and persistent effort and eventually produced a compressed-air driven torpedo which showed itself to be capable of travelling some 700 yards at an average speed of seven knots.

After this, Whitehead devised a special type of depth control mechanism to keep his torpedo at a fixed depth during its travel through the water. This was the mechanism which gave to the torpedo its first practical success.

Torpedo Trials

In July, 1870, a number of torpedo trials took place off Sheerness, and they were witnessed by a committee of Admiralty experts. In spite of the fact that the results of the trials were by no means satisfactory in all respects, the panel of Admiralty men reported very favourably on Whitehead's invention, with the result that in the following year this inventor sold his patent rights to the British Government for the sum of £15,000.

Other countries, too, purchased torpedo-making rights from Whitehead. The French nation negotiated for such rights with Whitehead in 1872, whilst in the following year the German and the Italian Governments acted in like manner.

Whitehead, now a man of position and affluence, continued to experiment ceaselessly with a view to perfecting his deathdealin ignvention. He introduced one improvement after another, until, eventually, the torpedo became an almost infallible, albeit an extremely costly device.

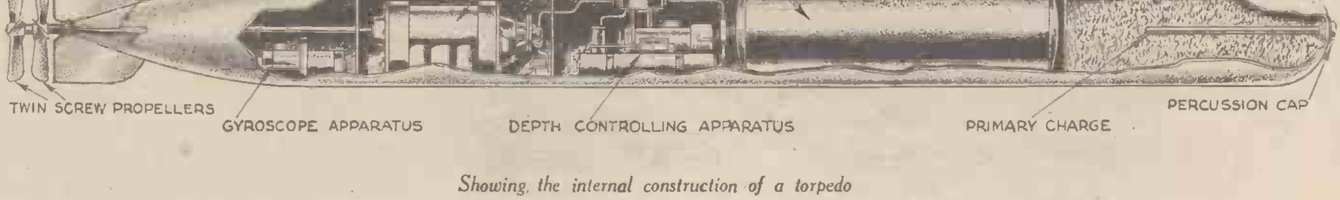
Recent improvements in torpedoes have, naturally enough, become the closely-guarded secrets of the nations in which they have been effected. Nevertheless, in its essentials, even the modern naval torpedo functions on the principles laid down so many years ago by Whitehead, it being, indeed, doubtful whether—short of a mode of utilising atomic power—any more effective operating principle for such a weapon could possibly be devised.

Principle of the Torpedo

In principle, the modern torpedo is simple enough, but in detail it is an extremely complicated device. The torpedo, as is now, perhaps, perfectly well known, comprises a cigar-shaped metal tube which is fired at a ship from a position either above or below the water line and which is capable of propelling itself in a perfectly straight line and with a very high velocity towards the object of its attack. Having made forcible impact with the latter, the charge of high explosives contained in the torpedo is detonated, resulting in an explosion and the consequent destruction of both the attacked vessel and the torpedo.

The explosive charge of the torpedo is carried in its head, beyond which projects the percussion device which, on making impact with any solid body, immediately detonates and so brings the explosive charge into violent and destructive action.

Immediately behind the explosive head or compartment of the torpedo is the air reservoir which, in most modern types of torpedo, comprises a steel tube of very high tensile strength. It is, indeed, virtually, a travelling air cylinder, and into this, purified air is pumped to a very high degree of compression.



Showing the internal construction of a torpedo

Naval Warfare

and uses of a Potent and World-wide Weapon

The Balance Chamber

At the rear of the air reservoir comes the " balance chamber " of the torpedo, whilst behind this is situated the engine chamber. Finally, an " after-body " carrying the tail and propellers of the torpedo completes the assembly of this much-used missile of naval warfare.

The reader may be surprised to know that before the air comes into contact with the engine, it is actually heated by means of a petrol burner. This heating results in the giving of an increased amount of energy to the air escaping from compression. Usually, in order to prevent the heating device from attaining too high a temperature, water is injected into it, the water being obtained from storage tanks formed around the compressed-air reservoir.

The Engine

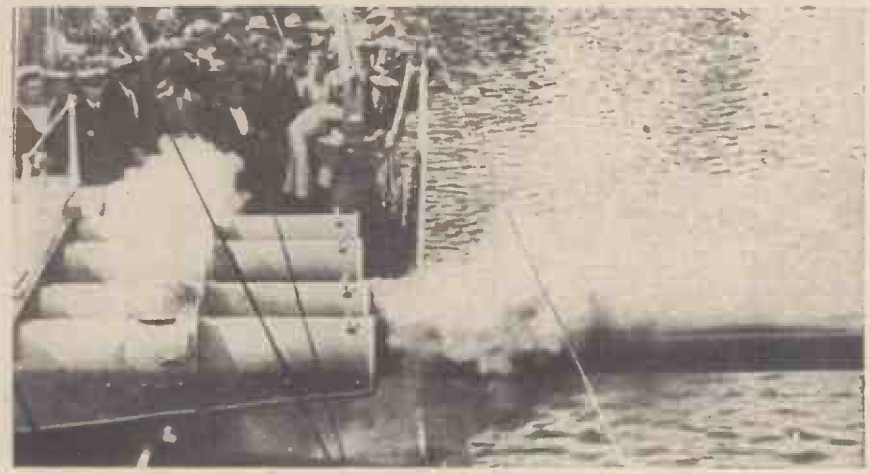
The heater operates within a sort of combustion chamber into which air escapes from the compression reservoir via a delicate type of reduction valve. Petrol is also sprayed into this chamber in quantity which is automatically regulated by the amount of air entering the chamber. In this chamber the petroleum vapour is ignited by means of a slow-burning fuse. Thus it is that a mixture of compressed air, burning petrol vapour and steam is passed on to the engine cylinders at a considerably high temperature.

The engine of a modern torpedo is a masterpiece of mechanism. It is frequently of a three or four cylinder type, automatically lubricated, and capable of developing about 500 b.h.p. Many portions of the engine are cooled by a circulation of sea-water which is automatically pumped through it from an opening in the side walls of the torpedo.

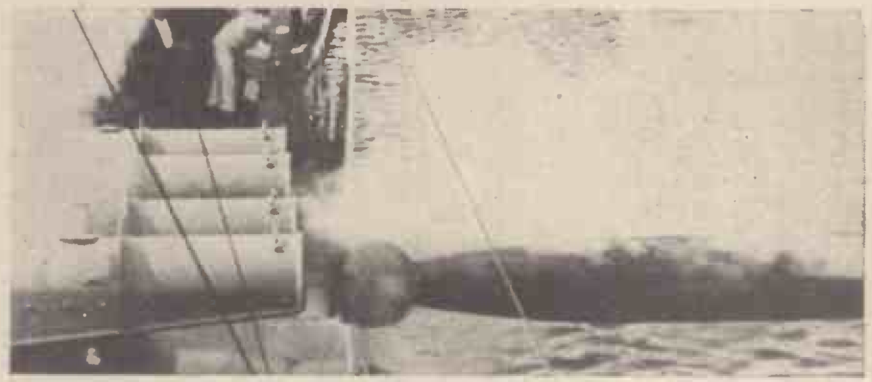
Lubrication and Cooling

The greatest attention has to be paid to the adequate lubrication and cooling of the torpedo engine, for if, as is many times the case, the torpedo " breaks " sea by leaping above the waves for even a few seconds, the engine, were it not adequately lubricated and cooled, would instantly heat up and fuse into a solid mass even within that short space of time.

From the engine, two concentric propeller shafts pass through the tail or " after body " of the torpedo, each of these shafts carrying a propeller. This propeller mechanism is so arranged that the two propellers revolve in opposite directions, this being necessary in order to rid the travelling torpedo of any heeling movement.



Firing a torpedo from a British warship



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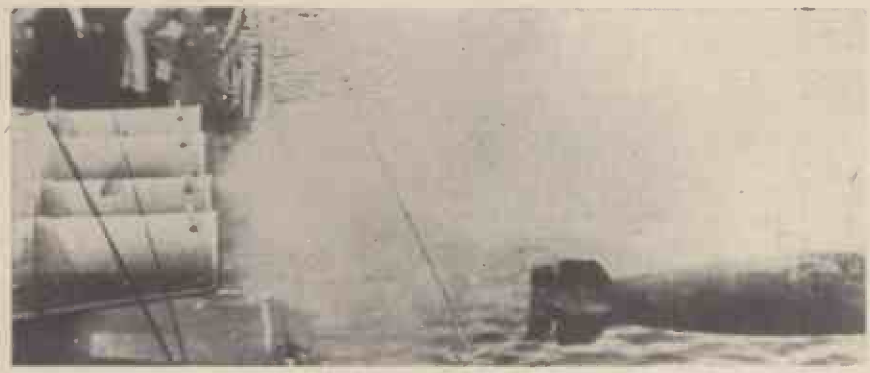

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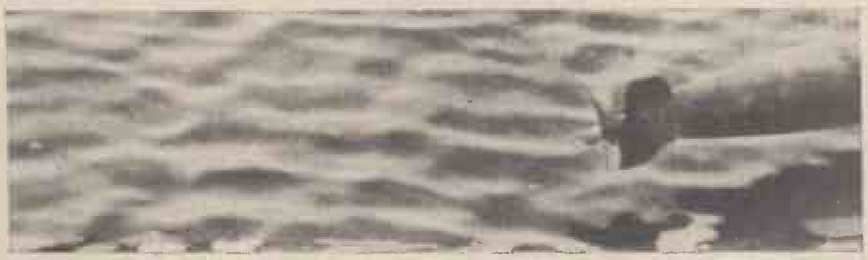

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Perhaps more interesting even than the amazingly efficient engine which propels the torpedo through the waves is the delicate mechanism which keeps it on a true course and, also, the means whereby it is enabled to travel through the water at any required depth.

Keeping a True Course

Torpedo inventors and designers experienced their greatest difficulties in keeping the missile on a true course through the water. Without such a mechanism the torpedo might even describe circles in the water, and, although, in some instances, it might only stray out of its course by a very small amount, such a deviation would be sufficient to render it ineffective when attacking an enemy ship.

Not a few devices were tried out for the above purpose of keeping a travelling torpedo in a straight line, but, eventually, the gyroscopic mechanism proved itself to be the most satisfactory for this purpose. Nowadays, as is well known, a torpedo is kept on its course by means of the revolutions of a small gyroscopic flywheel, weighing, perhaps, two or three pounds. This gyroscopic wheel is gimbal-mounted, and it is caused to run at extremely high speed.

The Gyroscope

The means by which the gyroscopic wheel maintains the torpedo on a straight course is really very simple in principle. It is dependent upon the fact that the axis of a well-balanced flywheel tends always to point in the one direction during the rotation of the flywheel, the flywheel itself tending always to rotate in one and the same plane.

Now, if, during the run of the torpedo, the latter tends to deviate from its course, the high-speed gyroscope flywheel remains in its original position. By so doing, matters are so arranged within the gyroscope compartment of the torpedo that the gyroscope makes impact upon a projecting cam which actuates a small valve admitting air to a miniature cylinder. This latter operates a control rudder and so brings the torpedo back into line.

The depth control of the torpedo is usually effected by means of a small hydrostatic piston operated by the external pressure of the water. This acts on a valve which controls the diving fins of the torpedo and so compels the travelling missile to remain at a given depth under the water. This depth control gear is necessarily a very delicate one, and it has to be very accurately adjusted in order that the torpedo may not alternatively leap above the waves and dive too deeply under them.

The Tubes

Torpedoes may, in general, be fired from "tubes" or cylinders which are carried by a ship or submarine below the water line, or, alternatively, they may be projected from similar tubes which are situated above the water level. In the latter case, the torpedo will leap from the elevated tube into the water and, sinking to its predetermined depth, will travel in a straight line towards its object with an almost incredible velocity and precision.

Practically the entire wartime utility of a torpedo is dependent upon its ability to travel in a straight line and at a very high speed towards the object of its attack. It is often essential, or, at least preferable, that the torpedo should travel below the water surface so that its presence may not be revealed until the fateful moment.

An average run for a torpedo is of the order of 3,000 yards, and, at a speed of some 45 knots, it will perform this journey in about 120 seconds. The torpedo engine unit must be so designed and constructed that it attains maximum speed within a few seconds after the firing of the torpedo. This vital requirement is attained in practice not through the existence of any special device, but, rather, in virtue of the great care and thoroughness with which the torpedo is designed and constructed.

Firing

A torpedo may be fired from a ship or a submarine either by means of compressed air or through the agency of a small charge of explosive. Torpedo firing tubes of the submerged type are usually fixed in direction, but those of the above-water variety can be trained on any object as desired.

Just before firing a torpedo which has been loaded into its tube, the interior gyroscope flywheel is set into rotation by the release of a strong spring and/or by a compressed-air jet. As the torpedo is projected forcibly from its firing or "impulse" tube, a projection within the tube, automatically engages a lever or arm on the side of the torpedo. This opens the main air-reservoir valve and thereby sets the engine into motion, releasing, at the same time a number of automatic mechanisms which all play their part in bringing the torpedo to bear speedily and accurately upon its chosen quarry.

Average Life of a Torpedo

The average "life" of a torpedo, once it is set into action, is, as we have already seen, about a couple of minutes. Then this closely compacted assembly of many mechanical ingenuities and automatic devices must inevitably share the fate of the object of its attack, which is to be blown to pieces.

It is, indeed, a curious commentary upon the creative mind of man that it is capable of devising and that it is, indeed, willing to invent some of the most marvellous and efficient trains of automatic, powerful and yet ultra-delicate mechanisms with the full knowledge that they can only be used for destruction and that, having destroyed, they will themselves also be annihilated.

There is, indeed, no constructive use for a torpedo. But a motor car normally operating at the efficiency of a modern torpedo would be an article of amazement the world over, and, as such, would contribute greatly to the happiness of civilisation generally.

NEWS OF THE MONTH

Ideas that are Novel and New

Conveniently Cleaned Kennel

A POET has said, "'Tis sweet to hear the watchdog's honest bark." This is true, although not only the burglar but the average listener finds too much of the honest bark disconcerting. Still the loyal animal deserves to be housed in a manner which ministers both to his health and his comfort.

It is a fact that kennels and also hutches of the usual type are not always easy to clean. One cannot conveniently reach the interior and scrub the corners and inmost recesses with that thoroughness which is necessary in order to do the job completely.

With the object of facilitating the work of cleaning, a kennel has been contrived with walls pivotally attached to their corresponding margins. As a consequence, these walls are capable of being turned outwardly. This will make it easy to apply distemper whose namesake is often so disastrous to puppies.

Coloured Targets for Darts

THE game of darts, during recent years, has become increasingly popular. It has also gained in respectability, if I may say so, without reflecting upon the social tap-rooms with which at one time it was almost entirely associated. To-day, for example, at A.R.P. posts, the worthy wardens—ceaselessly on the *qui vive* for air attacks—beguile the period of waiting by throwing feathered missiles at a long-suffering target.

An application has been accepted for a patent in this country relating to an invention, the purpose of which is to enlarge the possibilities of the game of darts. The device consists in the provision of a dartboard of a number of individual targets which may be of different colours, shapes and sizes. These targets may be coloured after the manner of the balls used in the game of snooker. In that case, darts could be played to similar rules. There may be, for instance, an outer ring of red targets and radially arranged yellow, green, brown, blue, pink, and black targets.

Each target is mounted in a cup or shell of metal or some other rigid substance and is composed of material into which a dart can easily penetrate. The targets are detachable, and one object of the invention is an improved method of attaching these targets.

Pocket Darts

THERE has also appeared another contrivance connected with the game of darts. The aim of the inventor is to furnish a type of dart which can be conveniently carried in the pocket or paper containers. The enthusiast who prefers to use his own dart will now be able to convey it to the place of play without risking damage to his pocket, his hand or the dart.

According to this invention, when it is proposed to pocket a dart, the nose is detached, the point is taken out and reversed and the head is reinserted in a recess. The nose is attached to the main portion of the body, in a bore of which the point is accommodated. Thus it can be carried on the principle of a pencil protector.

Audible Railway Signal

IN the present age, when the ingenuity of the inventor is so evident in every department of life, one may legitimately be allowed to express surprise that a really effective method of railway fog signalling has not yet been conceived. What is required is a foolproof system, so that even a blind motorman could pilot his train with perfect safety. A patent which appears to be at least in this direction has been granted in the United States. The device is officially entitled "Audible Railway Signal," and includes a diaphragm valve. In foggy weather, such a signal, though invisible, would orally authorise a driver to stop or proceed. This would relieve a railway company of the necessity of using the ordinary fog signal, whose detonation somewhat resembles that of an enemy bomb. Moreover, in war-time, such a signal might take the place of lights, which are hostile to the black-out and extend further than a modulated sound would reach.

A WEATHER-DRIVEN CLOCK

The Driving Force of the Atmos Clock is as Near Perpetual Motion as we are Likely to Attain. It Relies Upon Changes of Temperature to Supply the Winding Energy

The Atmos II clock which can be obtained in bronze-gilt or chromium. It measures 9¼ in. × 8¾ in. × 6¼ in.

THE Atmos Clock, strictly speaking, is not perpetual motion, but to all intents and purposes it can be claimed as such, because there is no necessity for winding it by hand, mechanically or electrically. It is propelled simply and surely without any human intervention by the variation of temperature and barometric pressure. The variations need only be minute. A change of 2½ degrees centigrade gives 41 hours winding power. The temperature is constantly changing and during 24 hours it is probable the clock is energised with a fortnight's reserve winding force. Even in centrally heated buildings this minute variation occurs.

Experience proves that throughout the world the daily variation of temperature is much greater than 2½ degrees, and it is obvious, therefore, that the winding power becomes accumulated. This is stored in a specially long mainspring which more or less remains under constant pressure at its maximum working capacity. With this reserve there is sufficient power to last one year even if the clock is placed in a vacuum where there is no change of temperature.

The Movement

The originality of the Atmos is not confined to the power unit. The movement itself is unique in that, owing to the extremely slow action of the moving parts (there is practically no wear and tear), together with the extra fine precision finish, the use of oil has been eliminated. This removes at once one of the most serious sources of trouble in the maintenance of clocks, as oil in time becomes dry and sticky, thereby necessitating a clock to be periodically cleaned.

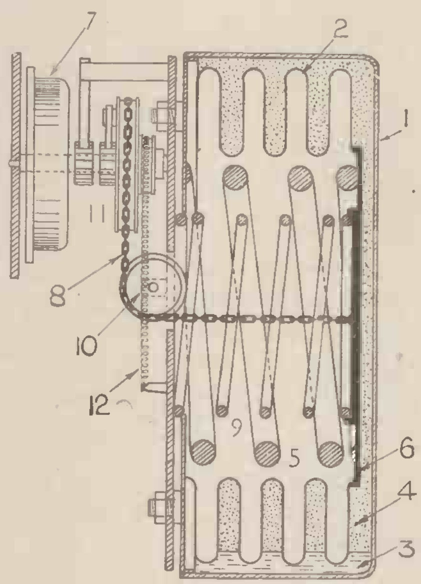
A very important advantage of the Atmos 11 is the simplicity and precision of the means of regulation. Owing to the remarkable constancy in the power tension the regulation is very sensitive. One complete turn of the regulating wheel produces a variation of only 12 seconds per 24 hours. It will be seen, therefore, that the adjustment is almost micromic. The balance oscillations of the ordinary escapement clock are 432,000 per 24 hours, but in the Atmos they total only 2,880.

The Temperature Motor

The Atmos motor consists of a drum, marked (1) in diagram, in the interior of which is assembled a flexible metallic bellows (2). The space between the bellows and the outer drum casing (4) is hermetically sealed and contains ether-chlorine in gas form.

With the slightest decrease of temperature some of the gas will liquify (at 3), and the interior pressure of the bellows will be lowered. A spring (5) under compression is mounted on the central surface of the bellows (6). This spring tends to keep the bellows in the open position as in the diagram. We will refer to this as the "compression spring."

When, on the other hand, the gas pressure is increased, the spring becomes further compressed and the bellows close like an accordion. When, later, the gas pressure may fall, the action is reversed—the springs expand, forcing the bellows open again.



A sectional view of the motor of the Atmos clock

Barometric Pressure

The change in barometric pressure also comes into play. If it is increased, the compression spring is assisted in forcing the bellows to the open position. If the barometric pressure is decreased the internal pressure of the bellows has less exterior opposition. It will be seen, therefore, that the effect of barometric pressure, although of secondary importance in providing the winding power, assists materially in livening up the accordion-like action of the motor.

Working within the compression spring (5) is a smaller spring which indirectly provides the winding power. It is fixed to the body of the clock and the other end is free. The spring is always under compression. At the extremity, adjacent to the bellows, is fixed a fine chain (8) which passes over a pulley (10), and is then attached to a larger pulley (11). This is fixed with ratchet action on the spindle in direct drive with the mainspring of the clock.

Winding the Mainspring

A fine coil spring (12) is mounted on the side of the main pulley drive for the purpose of taking up the slack in the chain when the bellows are being compressed. As the bellows expand again the pull on the chain turns the driving pulley and winds the mainspring.

The centre surface of the bellows has an area of 80 sq. cms. A difference in temperature of 1 degree centigrade will cause a variation in pressure of 50 grms. per sq. cm. The working force, therefore, is 4 kilogrammes (8½ lb.) per 1 degree centigrade change in temperature. The maximum compression of the bellows is 40 kilogrammes.

Provision has been made by which the clock cannot be overcharged with power. The maximum power of the intermediate spring (9) is lower than that of the clock mainspring so that if the mainspring is wound to full working pressure the intermediate spring can only expand itself to the point where it balances the mainspring and there remains. As the clock runs down so does the pressure of the mainspring fall. As there is a reserve in the intermediate spring the power is automatically returned to the mainspring which, therefore, must remain at a constant pressure. It could only be in artificial conditions that the intermediate spring fully expanded itself before the mainspring had reached its maximum working pressure. In practice, the tension of the mainspring is maintained at almost constant pressure—a very great advantage for precision timekeeping.

Features

The advantages of the Atmos clock is that the pendulum is suspended on an Elinvar spring which is unaffected by temperature changes, thereby assuring accurate timekeeping in any climate. The constant driving force ensures maximum precision and it eliminates the human element—forgetfulness. There is no electrical problems as with electric clocks and there is no wear and tear on moving parts.

The Atmos clock is manufactured by Jacgar-Le Coultre, one of the largest and oldest established watch factories in Switzerland, and the distributers for Great Britain and the colonies are De Travers, Ltd., of 88 Regent Street, London, W.1.

Harnessing Water

Practical Methods of Obtaining Power

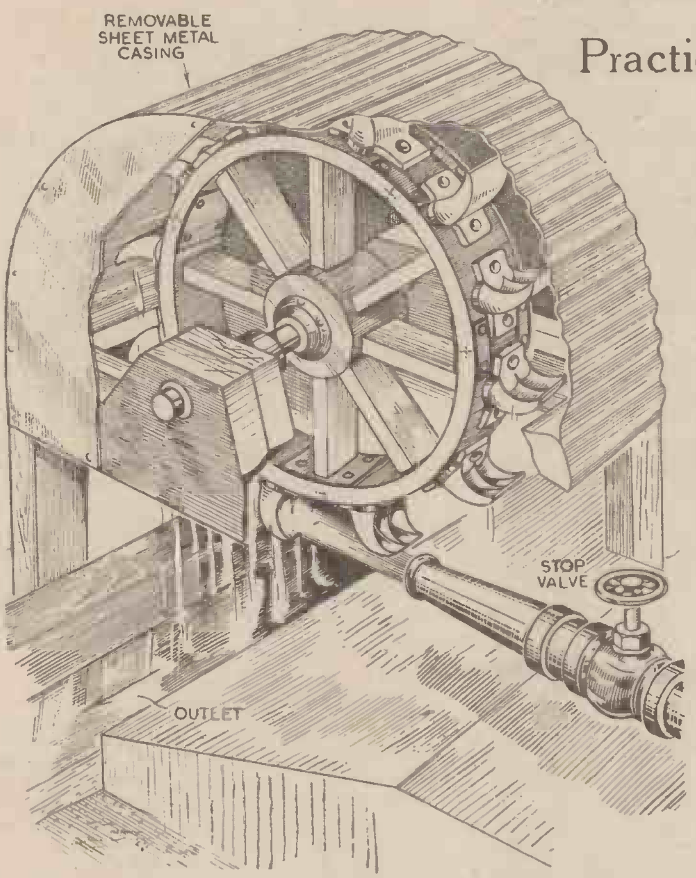


Fig. 1. — A simple arrangement for a Pelton wheel

WATER power is not available to any considerable extent in England, for although there are plenty of streams, the land is frequently too flat to provide a good head. Also the water flow is liable to considerable variation between wet and dry weather conditions. The picturesque old water mills that are still to be seen are being superseded by giant factories, or possibly the water wheel may be replaced by an oil engine.

A waterfall is always a source of power, but a slow stream flowing through meadowland is not. If it is possible to raise the level of the stream a few feet by building a dam without flooding the surrounding country, a head of water equal to the height of the dam is obtained and the stream becomes a source of power.

When considering the question of water power, the first step must, of course, be to see if the required power is available, and to do this it is necessary to ascertain the quantity of water flowing per second and the height through which the water can fall, or in other words we want to know the "flow" and the "head."

A Wooden Dam

The flow of a small stream can be arrived at by building a wooden dam or weir with a rectangular notch in the top as shown in Fig. 2. The depth of water flowing over the bottom of the opening will, in conjunction with Table I, give the flow in cu. feet per second. The depth should not be measured at the opening itself, but should be measured in still water not too near the opening, as shown in Fig. 2.

An approximate estimate of the flow can be made without the weir by measuring the average width and the average depth of the stream over a straight stretch of, say, 20 yd. to 30 yd. Then place a well-submerged float (a bottle partly filled with water will do) in the middle of the stream, and time the rate at which it moves, thus obtaining the velocity of the water in the middle of the stream. The flow and power available can be worked out as follows :—

W = Average width of stream in feet.
D = Average depth of stream in feet.
V = Velocity at centre in feet per second.
F = Flow in cubic feet per second.
H = Head of water in feet (measured from surface of water above weir to surface below).
P = Horse-power available.

$F = W \times D \times V \times .7$

$$P = \frac{W \times D \times V \times H \times 43.7}{550}$$

If the notched weir method is used in conjunction with Table I, the horse-power will be :—

$$P = \frac{F \times H \times 62.4}{550}$$

Fig. 2 — A notched weir for measuring water flow

Horse-Power

As an instance, suppose the stream has an average width of 9 ft., average depth 2 ft. 3 in., flow .8 ft. per second, and you can arrange a head of 4 ft., then the power will work out at 5.15 h.p. But the full power cannot be obtained in practice as no water motor is 100% efficient, so suppose we use a water-wheel with an efficiency of, say, 60%, then we might reasonably expect to obtain about 3 h.p. This may not seem very much for a stream of this size, but this is because there is only a small head. If this same stream were flowing down a mountain and a head of 200 ft. were available, one could quite reasonably expect a power output of about 150 horse-power, or even more, because the efficiency would be higher than with a water-wheel.

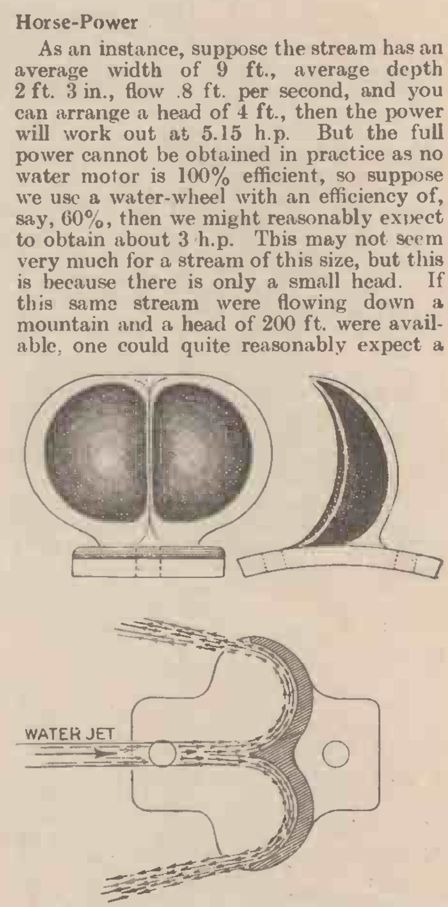


Fig. 3.—Bucket casting for a Pelton wheel

If the water supply appears to be capable of developing the power required, the next step is to consider the type of water-motor. These may broadly be divided into three classes as follows :—

(*a*) Water turbines, of which there are many different kinds, in all sizes, developing up to tens of thousands of horse-power. When properly designed for the work they have to do they are suitable for any head of water from the lowest to the highest.

(*b*) Pelton wheels, particularly suitable for high heads and small flows.

(*c*) Water-wheels of the paddle or bucket type suitable for low heads with a large flow of water.

Turbine and Water-Wheel

A turbine may be distinguished from a water-wheel in that it has two concentric rings of vanes, one ring remaining stationary and serving to deflect the water on to the ring of moving vanes. As some indication of the variations in design of this type of

Power

From Small Streams

water-motor, there are inward radial flow, outward radial flow, and axial flow turbines, and these may have horizontal or vertical shafts. Such machines are rather beyond the capacity of the amateur mechanic, also a great deal depends upon their design and the suitability for the particular purpose in view. The study of water turbines is a very involved affair, and it is recommended that the maker's advice be sought and the proper machine purchased from one of the firms of hydraulic engineers who advertise in the engineering periodicals.

A Pelton wheel, however, should not be beyond the capability of an amateur to construct, but careful consideration should be given to the design before construction is begun.

Assuming that the supply of water is ample, the power developed will depend upon the effective head of water and the size of the jet. Table II gives this information for various conditions, all figures for horse-power being arrived at assuming an efficiency of 75%.

Pelton Wheel

Fig. 1 shows a suggested general arrangement for a Pelton wheel; it should, of course, be covered in to prevent spray being thrown about in all directions. The diameter of the wheel should be worked out that will give the required number of revs. per minute when its peripheral velocity is as given in Table II. Obviously the smaller the wheel the higher the r.p.m.

The number of buckets should be arranged so that there is always one in line with the jet; the minimum number to achieve this result should be used. There is no advantage in putting on more buckets than necessary. A pattern should be made for the buckets (see Fig. 3) and the required number of castings obtained. The size of the buckets is not of first importance, the main point being that the water should flow smoothly and without spray until leaving the bucket. The radius inside each semi-bucket may be, say, about two to three times the diameter of the jet, the central division should have a sharp edge, but the cups should be rather less than a semicircle in shape so that the water when discharged from the bucket flows clear of the next bucket. About a dozen such castings bolted to an old motor-car wheel should make a satisfactory Pelton wheel providing the diameter is suitable for the r.p.m. required. One-half of a rear axle could also be adapted to form bearings for the wheel, the drive being taken off of the differential end.

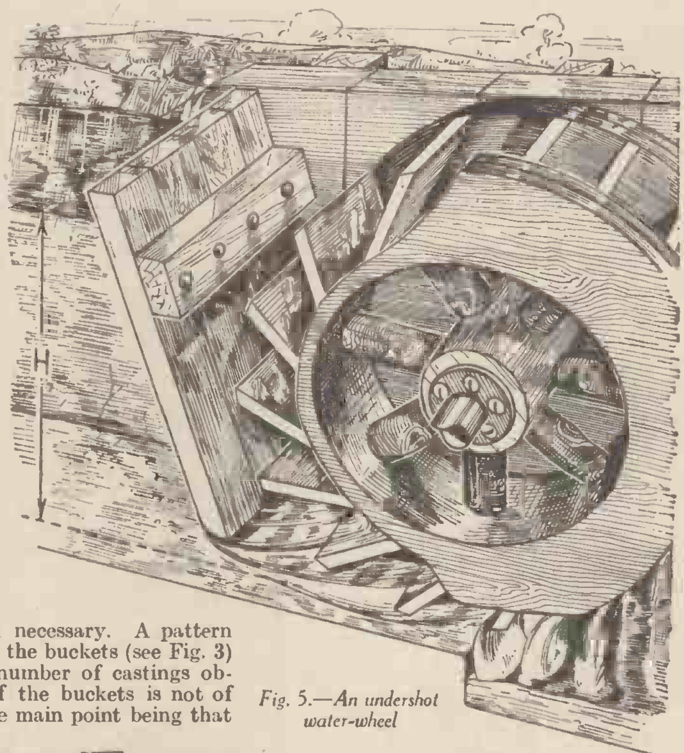


Fig. 5.—An undershot water-wheel

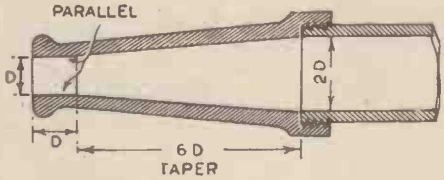


Fig. 4.—A nozzle for a Pelton wheel

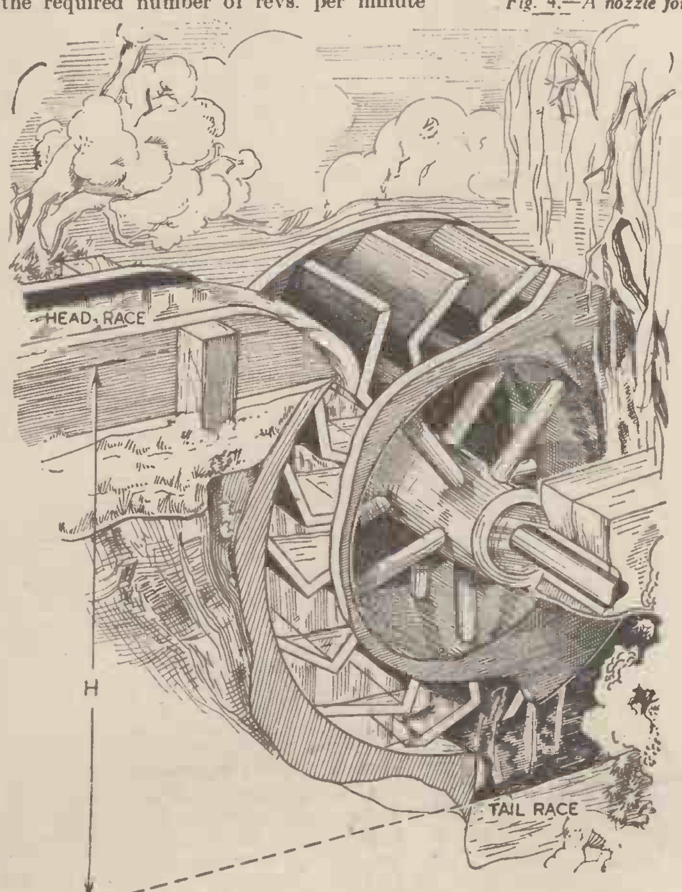


Fig. 6.—A breast wheel

Shape of Nozzle

The shape of the nozzle is an important detail. The inside must be smooth and well finished, and there must be no sudden change of diameter. Any elbows or junctions in the supply pipe should also be kept well away from the nozzle, as also should the stop-valve. A nozzle made of brass or gunmetal on the lines of Fig. 4 should give good results; the constant taper is not theoretically the best shape, but it is easier to make and there will be very little loss of power compared with the theoretical nozzle. A roughly made or makeshift nozzle will, however, waste a high proportion of the power available. Extra nozzles can be arranged to work on the same wheel if it is desired to increase the power and there is sufficient water available.

The arrangement of the supply pipe is of great importance if waste of power is to be avoided. It should as a rule be not less than three or four times the diameter of the jet if the pipe is very long, and should be as free as possible from sharp bends or elbows. It will be noticed in Table II that "effective" head is referred to. The reason for this is that there must always be a certain amount of loss of head due to friction in the supply pipe, and loss of head means loss of power. Table III is given to show loss of head in feet for various diameters of pipe and various rates of flow, so that the reader can work out the probable loss for his own installation. A study of this table will indicate the importance of a large supply pipe.

For low heads of water large quantities have to be dealt with and for such conditions a water-wheel is suitable. These are usually large for the power developed, but as they can be made principally of wood, they may yet be within the capability of an enthusiastic handyman.

Undershot Wheels

Undershot wheels may be used for heads up to, say, 6 or 7 ft., and should be arranged as shown in Fig. 5. The thickness of the water stream should not exceed 10 inches but may be of any required width. A sluice should be provided to regulate the flow.

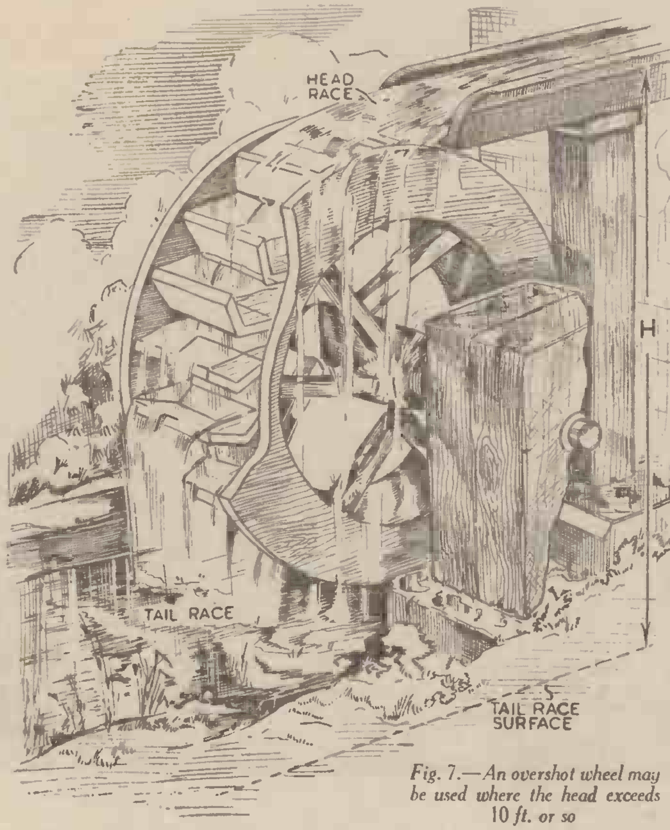


Fig. 7.—An overshot wheel may be used where the head exceeds 10 ft. or so

The paddles should be inclined to the radial line and should be at least twice the depth of the stream of water. Note the step below the axis of the wheel to allow the water to fall clear directly it has done its work. The velocity of the stream of water can easily be calculated when the head is known and its value in feet per second will be eight times the square root of the head measured in feet. The peripheral velocity of the water-wheel should be between half and .6 of the water velocity for best results, and the wheel diameter and r.p.m. should be arranged to give the required peripheral speed at full load. The power developed may be calculated when the head and quantity are known, as explained at the beginning of this article and an efficiency of 50% assumed.

For heads between 6 ft. and 12 ft. a "breast wheel" is used (Fig. 6). If the water enters the wheel above its centre it is called a high-breast wheel, or if below the centre a low-breast wheel. There are several variations in this type of wheel, chiefly in the manner in which the water is fed to the wheel. They cannot be dealt with fully here, but the same general principles discussed earlier apply. These wheels work by the weight of the falling water, and consequently carry a series of buckets on the periphery to hold as much water as possible.

Overshot Wheels

Overshot wheels (see Fig. 7) may be used where the head exceeds 10 ft. or so, and in this case the wheel should be made as large as conditions allow, as long as it does not dip into the water in the tail race. It will be seen that this type of wheel rotates in the opposite direction to the undershot and breast wheels, and being worked chiefly by the weight of the water carried on the wheel it is provided with buckets like the breast wheel. There should be about two buckets for each foot in diameter of the water-wheel, and the proportions should be as shown in Fig. 8. The power can be calculated as already explained and the width of the wheel should be arranged to deal with the required quantity of water without waste over the tops of the buckets.

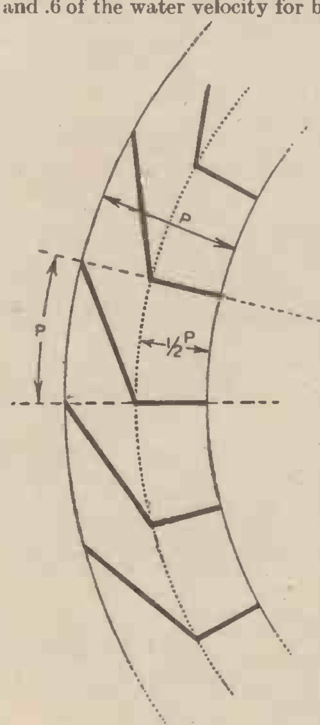


Fig. 8.—Proportions of buckets for overshot and breast wheels. There should be about two buckets for each foot in diameter of the water wheel, and the wheel should be arranged to deal with the required quantity of water without waste over the tops of the buckets

TABLE I

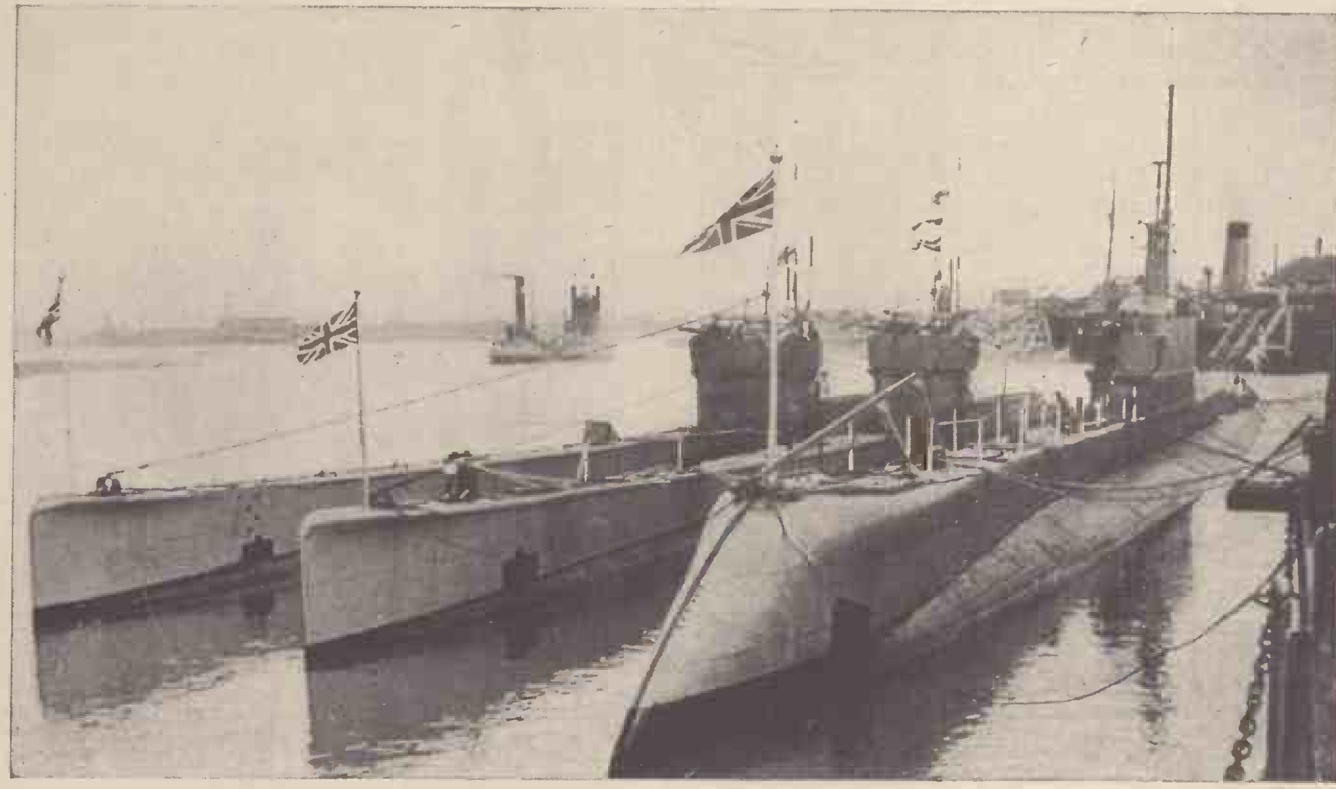
	Depth of Water in inches											
	1	2	3	4	5	6	7	8	9	10	11	12
Flow in cubic feet per second	.08	.225	.414	.637	.890	1.17	1.47	1.80	2.15	2.52	2.90	3.31

TABLE II

Dia. of jet	Effective Head Feet										
	10	20	30	40	50	60	70	80	90	100	
½ inch	.03	.08	.15	.24	.33	.43	.55	.66	.80	.94	Horse Power (E=75%)
	.03	.05	.06	.07	.08	.085	.09	.10	.105	.11	Cub. ft. per sec.
1 inch	.12	.32	.61	.95	1.3	1.7	2.2	2.6	3.2	3.7	Horse Power (E=75%)
	.14	.19	.24	.28	.31	.34	.37	.39	.42	.44	Cub. ft. per sec.
1½ inch	.27	.72	1.35	1.76	3.0	3.9	5.0	6.0	7.2	8.5	Horse Power (E=75%)
	.31	.44	.54	.62	.70	.76	.82	.88	.94	1.0	Cub. ft. per sec.
2 inch	.5	1.3	2.4	3.8	5.2	6.9	8.8	10.6	12.8	15	Horse Power (E=75%)
	.55	.78	.96	1.10	1.24	1.35	1.46	1.56	1.66	1.75	Cub. ft. per sec.
	13	18	22	25	28	31	34	36	38	40	Peripheral Vel. Feet per sec.

TABLE III

Water velocity in pipe feet per second	Diameter of Pipe, Inches								
	1	2	3	4	5	6	7	8	
2	2.37	1.18	.80	.60	.47	.39	.34	.30	Feet loss of head per 100 ft. of straight pipe
3	4.9	2.4	1.6	1.2	1.0	.80	.70	.60	
4	8.2	4.1	2.7	2.0	1.6	1.4	1.2	1.0	
5	12.3	6.2	4.1	3.1	2.5	2.0	1.8	1.5	
6	17.2	8.6	5.7	4.3	3.4	2.9	2.5	2.1	
7	22.9	11.5	7.6	5.7	4.6	3.8	3.3	2.9	



The Principles of the Submarine—Part 2

By R. L. Maughan, M.Sc., A.Inst.P.

The Periscope is the Eye of the Submarine, and In Recent Years has Developed Added Roving Powers so that it can View the Sky as well as the Sea

THE water ballast tanks carried by a submarine are of two types. These are the main water ballast tanks which are arranged symmetrically about the keel in the spaces between the inner pressure hull and the outer hull, and the smaller auxiliary trimming tanks which are lodged in the narrow confines at the extreme ends of the hull. The main water ballast tanks have a larger capacity and take the bulk of the water necessary to destroy the reserve buoyancy of the boat to bring about its submergence. Each tank is fitted with two valves, one in the tank bottom giving direct access to the sea and the other in the top of the tank to act as an air vent. When the submarine is in the normal surface cruising condition these tanks are filled with air at or just over the atmospheric pressure, the air valve being closed and the sea valve open and under the surface. The onrush of sea water through the open valve is prevented by the pressure of the air trapped in the tank, and any partial flooding of the tank due to an extra surge of water through the valve is combated by the automatic compression of the enclosed air.

Diving

A dive is initiated by the simple operation of opening the air vents in all the main ballast tanks to allow the sea to enter under its own pressure through the lower valve, the air being forced out through the open vents. When the tanks are filled with sea water the air valves are closed and the sea valves left open in readiness for the reverse operation of discharging the tanks. At the end of the dive the hydroplanes are rotated into the neutral position and the submarine enters upon its underwater course in a horizontal line. Recourse is made if necessary to the auxiliary trimming tanks in order to adjust the boat to a level keel. There are two of these tanks, one at either end of the submarine hull, and permanent communication is established between them by a tube which traverses the length of the boat. In the normal working condition they are shut off from the sea, but hold a small amount of water which may be transferred wholly or in part from one tank to the other by a water pump operating through the connecting tube. A small transference of weight in this way from one end of the submarine to the other is usually sufficient to correct the delicate poise of the vessel and to bring it to an even keel when in the submerged condition, but a continuous transference is necessary while the boat is being navigated on the surface under the motive power of its Diesel engines in order to counterbalance the redistribution of weight which occurs when fuel oil is removed from the storage tanks and consumed by the engines.

The Main Tanks

The main tanks are emptied when an ascent to the surface is to be made by blowing the water out through the open sea valves under a blast of air. This air is stored in a highly compressed state in cylinders housed within the hull, and is supplied to the ballast tanks through a valve which is directed towards the pressure hull wall inside the tank. The strength of this hull is easily sufficient to withstand the impact of the air blast and leaves the less robust wall of the tank formed by the outer hull plates to take the smaller strain of the pressure difference between the external sea water and the internal blown air. The cylinders are recharged when the submarine rises to the surface, the air supply being drawn direct from the atmosphere through open hatches by an air compressor worked from the Diesel engine drive. As a precaution it is customary to store at any one time an adequate supply of air to be able to discharge the ballast tanks several times over if necessary.

Although submarine construction dates from the year 1624 when the Dutchman, Cornelius van Drebbel, built a vessel out of wood and leather and successfully demonstrated its practicability as an under-water craft by propelling it with oars slotted through flexible leather glands in the sides, it was not until 1902 that the periscope became a permanent feature of the submarine. Previous to that date submarines travelled blind and were obliged to make frequent visits to the surface in order to take cognizance of their whereabouts.

The Periscope

The periscope is the eye of the submarine, and in recent years has developed added roving powers to enable it to view the sky as well as the sea. In structure a periscope is really a set of three telescopes arranged end to end in a vertical tube with a prism at the top and bottom of the tube. The upper prism serves to reflect the light from the sighted object into the top of the tube and the lower prism from the bottom of the tube into the eye of the observer, while the telescopic system in between produces the necessary magnification. The optical arrangement of the instrument is illustrated in Fig. 6. Any system of lenses, prisms and mirrors which receives a parallel beam of light at one end and transmits a parallel beam from the other end after converging or diverging it in between is said to be telescopic. It will be seen from Fig. 6 that by this definition the two lenses C and D form one telescope, the three lenses E, F, and G a second, and the remaining system HKLMN a third. A telescope is made up

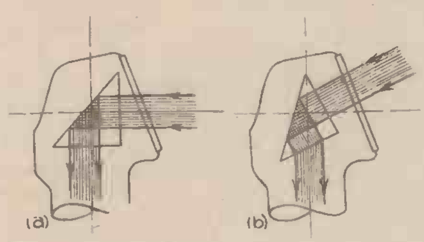


Fig. 7.—Showing elevation of view operated by upper prism

essentially of two lenses, the first the objective to receive the parallel beam of light from the sighted object, and the second the eyepiece to transmit a parallel beam to the eye of the observer. If the lenses are both convex the telescope is said to be astronomical and produces an inverted image of the viewed object. If the objective is convex and the eyepiece concave they form a Galilean telescope which produces an upright image.

Simple Instruments

In practice single-lens objectives and eyepieces are employed only in the very simplest types of instrument where slight distortion of the image due to spherical aberration and slight colouring of the image edges due to chromatic aberration are not considered as serious defects. Where it is of the utmost importance to record the true form and colouring of a sighted object as it is in the periscopic observation from a submarine, objectives and eyepieces each consist of a series of convex and concave lenses cemented together to form compound lenses which are free from colour and distortion defects, that is they are both achromatic and anastigmatic. Compounds of this type are represented in Fig. 6 by the twin lenses D, E, G, H, N. Since the periscope tube contains the equivalent of two astronomical telescopes (EFG and HKLMN), each of which inverts the image, and one Galilean telescope (CD), which keeps the image upright, the final image produced by this combination will also be upright. In addition there is an inversion at each prism reflection, so that the ultimate image seen by the observer will still remain upright. The twisting of the beam of light to produce these successive inversions may be traced in Fig. 6 in the courses of the extreme rays of the beam marked "a" and "b."

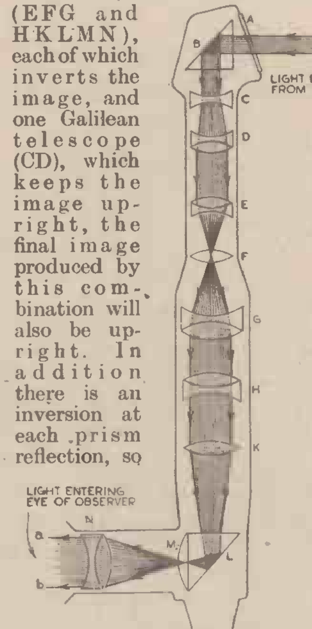


Fig. 6.—Vertical section of a periscope showing the optical system and path of the central beam

Galilean Telescope

The purpose of the Galilean telescope is to provide the periscope with two different powers of magnification. It will be seen from Fig. 6 that the Galilean telescope is reversed with respect to the observer's eye and the two other astronomical telescopes, its concave eyepiece C being situated between the upper prism B and its convex objective D which is directed towards the objective E, belonging to the middle telescope. When all the lenses are aligned along a common axis the observer has a view through three successive telescopes, but as the end telescope is reversed the view obtained has a low-power magnification and the image is not much enlarged. The advantage of this low-power vision is that rapid reconnaissance may be made over wide tracts of seascape or sky by rotating the periscope about its vertical axis through a relatively small angle. When the high-power magnification is required the Galilean telescope is swung out of the line of vision to leave the two astronomical telescopes to bear upon the object with their added powers freed from the effect of the reversed Galilean telescope. Under these circumstances, the field of view is well filled by the highly magnified image, and the minute examination of details is possible over a necessarily limited range of vision. It will be appreciated that the removal of the Galilean telescope to increase the power of the system rather than a reversed astronomical telescope does not alter the number of inversions of the image during the course of the beam from the periscope window to the observer's eye, and so the final image still remains upright.

In the modern submarine the periscope's range of vision is made to extend to the sky as well as to the surface of the sea. For this purpose the upper prism is made to rotate about a horizontal axis in order to incline its reflecting surface at a smaller angle to the vertical. In this position light received from higher altitudes is received on the surface of the prism presented to the window and is reflected from the back surface down through the system of telescopes into the eye of the observer. (See Fig. 7.)

Keeping out the Sea

The sea is prevented from entering the periscope by means of the plate glass window built into the tube head. (A in Fig. 6.) And the remainder of the tube is a water-tight metal casing which passes through a water-tight gland pierced through the hull to emerge above the conning tower. The tube is raised to its full length when observations are to be made, and withdrawn through the gland when the submarine submerges, by the power of the boat's electric motors. The unquestioned importance of the periscope as part of the submarine's equipment is responsible for the continued study and experiment devoted to its design and construction by the expert in metallurgy as well as in optics and engineering. The metal of the periscope tube is a bronze which has, at the same time, the property of being able to resist corrosion through prolonged contact with sea water, the required rigidity to withstand the strain of being forced broadside on through the water as the submarine proceeds on its course, and the merit of being totally non-magnetic which prevents it from influencing the boat's navigation by disturbing the compass card.

Fig. 8 illustrates the external mechanism at the base of the periscope tube by means of which the observations are controlled. The eyepiece E, with its guard ring of rubber, is centred in the base of the tube—which also carries the control screws S and T which are used to move the lenses in the adjustment of the periscope focus. Two arms AB protrude from the base piece and by means of them the base and the entire column of the periscope above it may be turned about a vertical axis in order to make the line of vision sweep through any desired angle in a horizontal plane. The indicator I, carried by the base, moves over a fixed scale K engraved on the circular rim of the tube containing the periscope, and automatically registers the angle between the line of vision and the line of the boat's keel. The handles at the ends of the arms are able to rotate about the common axis AB of the arms themselves, and by turning the handle A the power of the periscope is adjusted to the high or low value by swinging the Galilean telescope out of or into the optic axis of the lens system, whilst the manipulation of the handle B varies the inclination of the prism in the periscope head in order to elevate the view from the sea to the sky. When the periscope is not in use the two arms fold upwards into vertical rest positions against the periscope base to economise the space in that part of the control-room.

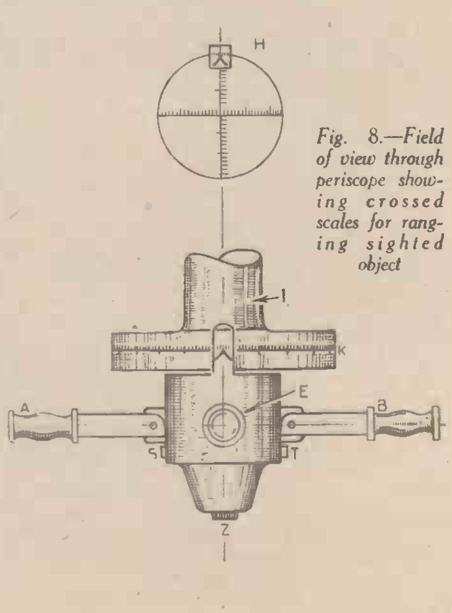


Fig. 8.—Field of view through periscope showing crossed scales for ranging sighted object

Main Function

The main function of the periscope is one of plain observation, but in addition to this work of surveillance it is also used as a range-finder. For this purpose its field of view is divided into four quadrants by two cross-wires situated in the eyepiece in such a position that their image is permanently in focus in the circular field of view. (See Fig. 8.) Superimposed on their image are gauge lines marked along the length of each cross-wire, and by means of them an estimation may be made of the size of a sighted object, its distance from the submarine and the speed at which it is moving, while at the same time an inset image of the reading of the main indicator of the periscope's angle of observation is projected into the field of view. (H in Fig. 8.) This device enables the observer to consult this reading without having to remove his eye from the periscope eyepiece. The calculations of the size, speed and distance are greatly simplified when the cross-wire observations may be compared with known data about the sighted object. If this object is a ship whose length is known, its speed may be at once gauged from the time its image takes to move completely across the vertical cross-wire, and if it is viewed broadside on its length subtends at the observer's eye an angle indicated on the cross-wire graduations, so that the calculation of its range is made by dividing the ship's length by the angle it subtends, in accordance with the well-known geometrical principle.

Fixed Line of Sight

The tendency of the motion of the submarine in the sea to upset these calculations by making it difficult to keep a fixed line of sight on the object is counteracted by the action of a small gyroscope situated in the bottom of the periscope case and set into motion by the control screw Z. (Fig. 8.) Its effect is to maintain a steady line of vision from the eyepiece to the sighted object in spite of the rolling or pitching of the boat.

The apparatus of the periscope's base is centrally situated in the submarine's hull immediately underneath the conning tower. This region is the control-room, the position of which makes it highly adaptable to the command and control of the boat's interior and to the maintenance of communications with the outside world. The entire design of the periscope and its controls makes for simplicity, efficiency and economy of operation. The observer stands with an eye applied to the eyepiece and a hand on each of the arm handles. A turn of the arms rotates the periscope tube and sweeps out a view over the surface of the sea. A twist of one handle elevates this view and sends it over the sky; a twist of the other changes the magnification of the view and makes possible the rapid reconnaissance of large regions or the detailed examination of a localised region as required, whilst the control screws for varying the focus and setting the gyroscope into motion are conveniently at hand on the casing of the periscope base.

MANUFACTURING GLASS

Various Processes in Use To-day

GLASS is a soda lime silicate. That is, it is made from silica (sand), soda, and lime. If sand is mixed with soda (in the form of soda ash or saltcake) and heated, the soda melts and the sand dissolves in the soda. If there is an excess of soda, on cooling a thick syrupy liquid is obtained, but if more sand is added a hard, transparent, glassy substance results, but this, unfortunately, is soluble in water and is known as waterglass. By the addition of lime, the solubility of the sodium silicate is reduced, and with a sufficient quantity of lime a durable glass is obtained which will stand up to the weather and to all strong acids except hydrofluoric acid.

The Processes

All processes of manufacture are governed first by the article which it is required to make and, secondly, by the physical properties of the material employed. In the manufacture of glass the principal physical properties which influence the processes are :—

1. *Viscosity*. Glass has not a definite melting point. If the glass is heated, it first softens so that it can be bent; as the temperature rises it reaches a point when the glass becomes a thick, syrupy liquid, which can be gathered on the end of a pipe and blown, and finally at higher temperatures it becomes a thin, watery liquid.

2. *Devitrification*. Although weathering properties can be assured by a high lime content, there is always the danger of crystallisation, or devitrification, occurring. Above a certain temperature, known as devitrification temperature, glass may be kept in a liquid condition without any change occurring, but if the glass is kept below that temperature for any length of time, crystallisation or devitrification occurs. It is, therefore, essential in any process that the time taken to complete the operation shall not allow of devitrification. The tendency to devitrify can be reduced by decreasing the amount of lime and increasing the soda, but this can only be done at the expense of the weathering properties.

3. *Annealing*. A hot sheet of glass left to cool naturally will break, and in order to obtain whole sheets of glass, the sheet must be annealed, that is, cooled down gradually in what is known as a lehr.

4. *Melting*. The melting process takes place in three stages : (1) The initial melting. That is, the chemical reaction between the three ingredients, and this results in a sticky mass full of bubbles. (2) The next stage is the fining operation, which consists simply of raising the temperature so that the glass loses its viscous nature and becomes quite watery, thus allowing the gases forming the bubbles to rise to the surface. At this stage the glass is so thin that it is quite unworkable. (3) The third stage consists of cooling the glass down to a temperature where it is of the correct consistency to proceed with the particular process which is desired.

The Glass Bath

In feeding the tank, the raw material, which consists of the actual ingredients and broken glass, falls from a hopper carried on an overhead crane, into what is known as the filling pocket, this pocket being the jutting-out portion of the actual glass bath. A glass tank, which may be as large as 120 ft. long by 36 ft. wide and 5 ft. in depth, has sides and bottom made of clay blocks and the roof of silica bricks, and may contain anything up to 1,000 tons of molten glass, with temperatures varying from 1,200° C. to 1,450° C. in different parts of its length. There is no end to the variations which may be made to the shape of the tank so as to melt the "frit" at one end to produce seedless and homogeneous glass at the other. It is comparatively easy to forecast the convective currents in a beaker, but the convective currents in a glass tank of large dimensions are more difficult, and to understand them is to know how to produce good glass. Actually, the amount of glass flowing down the middle of the tank due to convective currents is about twenty times as much as that being withdrawn at the working end.

Polished Plate Glass

This was originally made by melting the frit, i.e. the mixture of sand, soda, saltcake, and limestone in fireclay pots, each holding approximately one ton of molten metal, which was heated for 17 hours in a gas-heated furnace at a temperature of approximately 1,600° C. At the end of this period mechanical tongs gripped the pots and conveyed them to the casting tables made of iron, on which the molten glass was slowly poured. A roller covering the whole width of the table then moved across it, flattening the molten metal into a plate, the thickness of the glass required being regulated by adjustable guides at the side of the casting table. The resultant glass was translucent but not transparent, its surface being rough and coarse, but the inside crystal clear. This glass was slowly annealed to release any internal strains and then subjected to a grinding process by which the rough surfaces were smoothed down on rotating circular tables by means of revolving iron-shod discs, the abrasive being sand or emery and water. After the grinding process the plate was polished on both sides individually by means of felt-padded discs, the polishing agent being rouge and water.

About 1921 a further process was introduced called the Bicheroux process, in which, although the glass is melted in pots as in the old process, it is rolled into a sheet between two rollers instead of being poured on to a table in front of a single roller, with a resultant flatter sheet, which means less loss of time in the subsequent grinding and polishing operation.

This method gave place to a continuous process in which the molten glass flowed directly from the tank between rollers into the lehr or annealing chamber, from whence it was cut into lengths and subjected to a grinding and polishing process on a continuous machine. The length of this machine was 600 ft. and was evolved at St. Helens.

The latest adaptation of this method is the direct flow of the sheet from the tank to the warehouse, where it arrives in a polished state without handling, having been ground and polished on both sides simultaneously *en route*.

This is an achievement unsurpassed in the history of glassmaking and has entailed an expenditure of over one million pounds sterling in research and erection of plant. The plant itself, from the melting end of the furnace to the point of delivery of the finished product, is over one thousand feet in length.

A Low-Wing Petrol Monoplane

By Major C. E. Bowden

(Concluded from page 222 of last month's issue)

A front view of the model

The Undercarriage and Tail Wheel

YEARS ago I developed a simple type of undercarriage for petrol models with two main built-up steel wire legs that are faired with balsa and bound with silk, and doped. The two rear legs are coil wire springs.

This was fitted to my record-holder, "The Blue Dragon." This model has flown from 1934 to date and completed an enormous number of flights, and the undercarriage, which is perhaps the most highly stressed part, has never had any repair of any sort.

It is not beautiful, but it works, which is the main essential point. I have developed a better-looking undercarriage since, but it is not so reliable, although it certainly has the essential back and then upward shock-absorber movement.

In the case of a low-wing model there must be a limited rearward travel or the rear legs will strike the wing. It was, therefore, decided to revert to the trusty old type of undercarriage for the "Gull," as flying results always come first when there is any question about their clashing with looks.

It is hardly necessary to describe the undercarriage construction because the elevation is self-explanatory, and if the reader will refer to the photograph of the model as shown, on the ground the point to be observed is that the travel of the undercarriage is first back then upward, and that the action is very resilient. This permits the model to glide into the ground. A model is not put down 3-point on to the ground as in the case of a full-sized aeroplane.

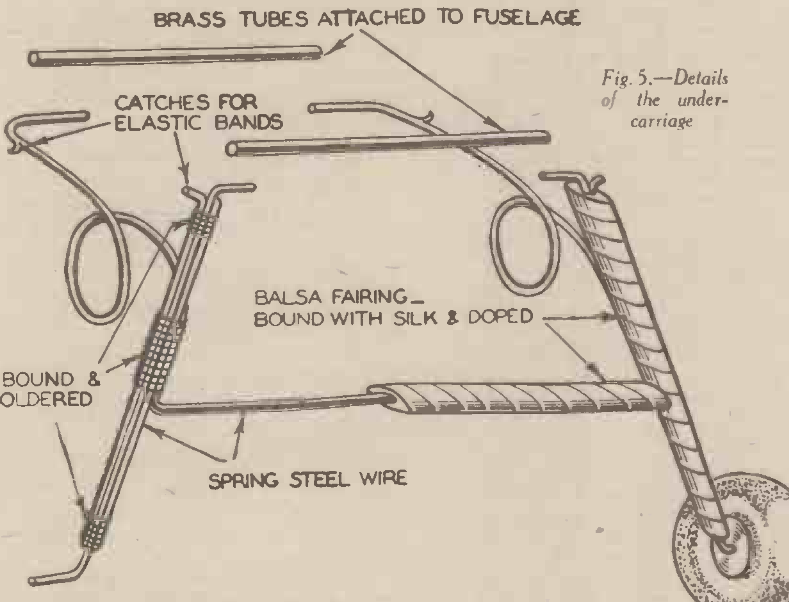


Fig. 5.—Details of the undercarriage

The recent development of the tricycle undercarriages for full-size aeroplanes is a similar idea, and allows the aeroplane to be flown and glided at reasonable angles straight into the ground without flattening off. This is as it should be.

The Detachable Tail and Detachable Fin

The shape of the tail is evident from the drawings of the general view plan. A full-size drawing must be made from this. You should also refer to Fig. 8, which is a sketch of the tail unit showing constructional details. You will notice that the tail is detachable and placed on the rear platform on the fuselage, and is kept in position by elastic bands from the two pegs in front to the wire hooks on either side of the fuselage, and also from the hook on the tail end of the fuselage.

The fin is made separate for ease of transport, and has two $\frac{1}{8}$ in. round birch dowel pegs glued into it. The bottom ends of these dowels fit into the 1 mm. 3-ply covering of the tail centre section. Glued below this covering there is a block of solid balsa where each dowel peg fits to strengthen.

There is a wire hook at the front and at the rear of the fin. Elastic bands keep the fin hard down to the tailplane. The fins must be set straight at all times. This will be explained later. The fin is made of three laminations of $\frac{1}{16}$ in. sheet balsa cut to the outline shape, and then hollowed out, so that a proxal outlined remains. The laminations are glued together and weighted until dry. The outline edge is then streamlined off by the use of a razor blade and sandpaper. Streamline ribs of $\frac{1}{8}$ in. balsa sheet are then fitted into the centre.

The tail and the separate fin are then covered with thin jap silk, using photo paste as an adhesive. Now spray the silk with water when covering, and this will tighten the silk up when dry.

Now give one coat of clear full-size glider dope (obtainable from the model shops that specialise in petrol models).

The Detachable Wing Built in Two Halves

The fitting of a low wing to a large and heavy model is always a knotty problem, as the wing must be fairly rigid and yet must knock off if the model flies into a tree.

On this model the wing is built in two halves for portability, and the two halves are kept together by wire hooks and elastic bands. The wire hooks must be not less than 16 s.w.g. wire and must be very well bound and glued into position as they have considerable loads to carry.

There have been added wire strengtheners to the break in the wooden spars where the dihedral angle comes, and up to the two No. 1 3-ply ribs.

The hooks are bound and soldiered to these wire strengtheners and the whole are bound to the main spars with thread and glue.

For the first few bays the top and bottom

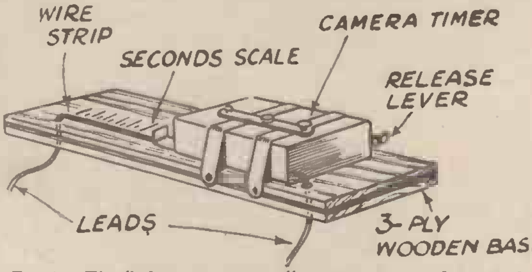


Fig. 6.—The flight timer to cut off ignition at a predetermined time

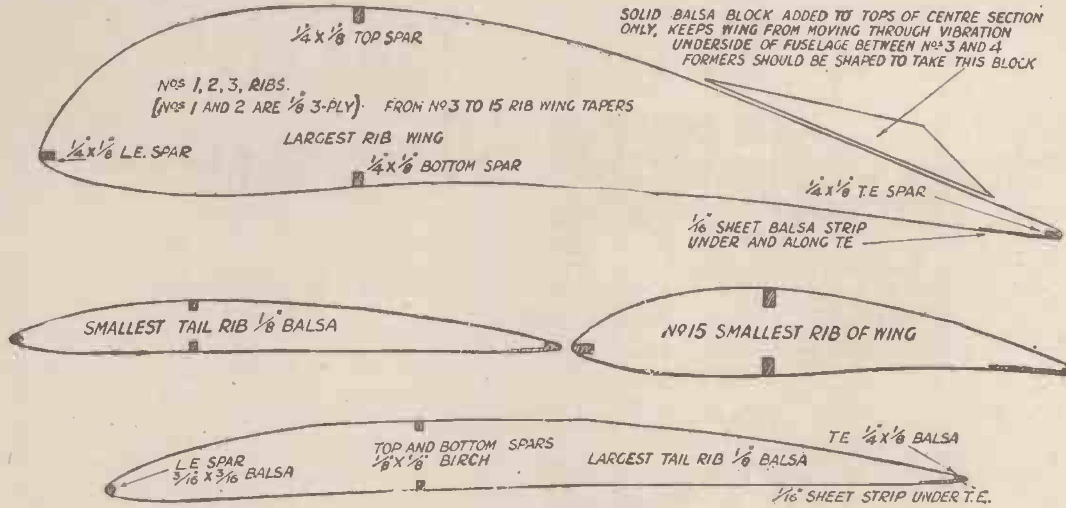


Fig. 7.—The wing and tail sections

main spars are covered in on both sides by $\frac{1}{16}$ in. sheet balsa glued on. This makes a strong box spar in the centre. The top and bottom main spars are of $\frac{1}{4}$ in. by $\frac{1}{8}$ in. spruce. The L.E. and T.E. are also of $\frac{1}{4}$ in. by $\frac{1}{8}$ in. spruce.

I first of all built a platform from matchboarding, upon which to make the wing halves. This platform has the necessary dihedral in it.

The drawing of the wing can be put on to the platform, with some greaseproof paper over it to prevent glue sticking to the drawing. The wing is then built over the full-sized drawing, and when the glue is dry a covering of thin jap silk is put on, using photopaste as an adhesive, and damping the silk with water from a scent spray. As the under-surface of the wing is concave and it is essential to keep this section, the bottom must be covered first.

The fabric has to be stitched to each rib by large stitches of thread through the fabric, around the rib and back through the fabric.

When the two wing halves are covered, they are left to dry, and then given one generous coat of full-strength, full-size, cellon glider dope, as in the case of the fuselage and tail plane.

When the dope is half-dry, and has just lost its tackiness, the wing halves are placed upon the wing bed, and flat irons are used to weight the wing so that it does not distort whilst the dope is drying. The idea of using glider dope is that, once dry, it forms a hard covering that seldom distorts and is not easily affected by weather. It also makes a vastly more rigid and stronger wing than if many coats of thin model dope are used. It dispenses also with all internal bracing.

It is very important to give the wing tips a few degrees of washout. This is done by placing small balsa wedges about $\frac{1}{4}$ in. thick under the trailing edges at the tips only. The washout will set in as the glider dope dries with its weight and top of the wing halves. When dry, leave several days to really harden, with weights on.

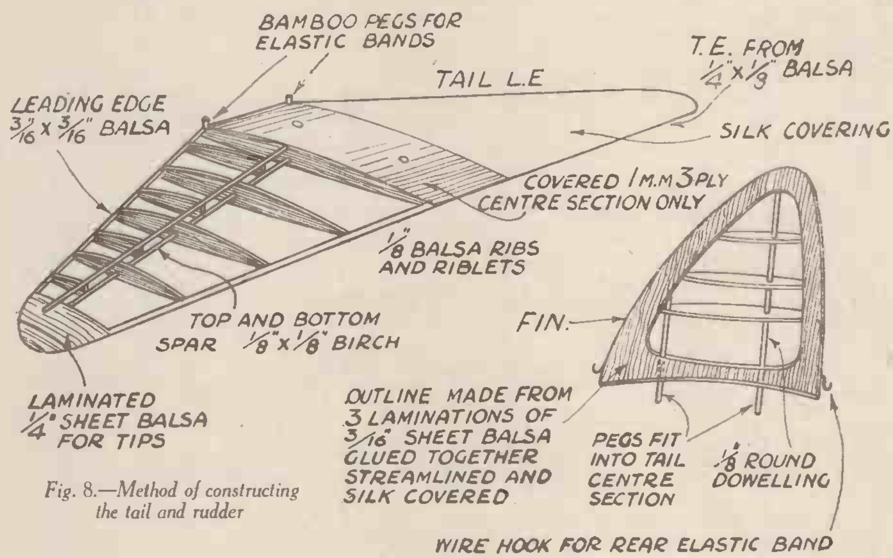


Fig. 8.—Method of constructing the tail and rudder

It should have been mentioned that under the trailing edge spars of the wing halves, a strip of flat $\frac{1}{16}$ in. balsa sheet about $1\frac{1}{4}$ ins. wide is glued, so that the rear ends of the ribs are also glued to this strip. This prevents distortion developing in the T edge.

The main balsa ribs are spaced every 4 ins. apart, and are cut from $\frac{1}{8}$ in. balsa sheet. Every 2 ins. and between the main ribs there are $\frac{1}{8}$ in. 3-ply wood, and over the top and bottom of these central ribs, a covering of 1 mm. 3-ply wood is glued. This makes strong wing centres for the wing halves to butt up against each other.

There are two small dowels glued into the right wing half and protruding $\frac{1}{2}$ in. only, and two holes drilled opposite in the left wing half No. 1 rib. These are merely to locate the two halves. The wings are otherwise kept together by the tension of the elastic bands.

On this page is shown the largest and smallest rib of a wing half. From these the tapered wing can be drawn full size.

Flying the Model

If you are a novice—and this article has been written for the beginner, and in considerable detail—it is suggested that you get to know your engine by running and starting

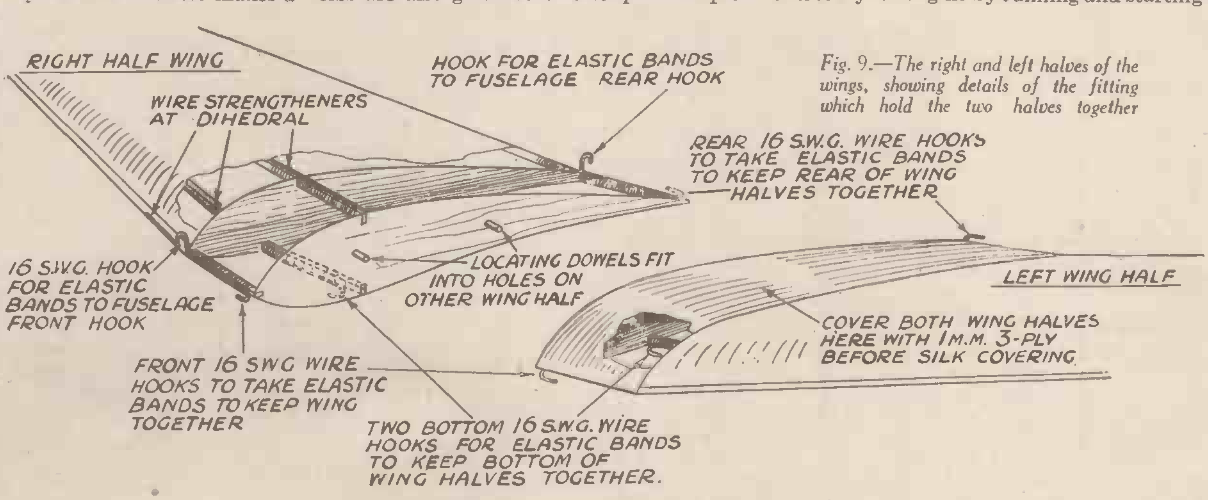


Fig. 9.—The right and left halves of the wings, showing details of the fitting which hold the two halves together

it on the bench first, and then on the fuselage, whilst you are completing the rest of the model. Model engines become simple, when you understand their peculiarities.

Now get the gliding trim of the model correct. The model must be a perfect glider if you wish to get good power flying followed by flat glides to good landings. Any other type of flight is not worthy of a decent model, neither should any modern aero modeller be satisfied with less.

To get glide-perfect, see that balance is correct. The point of balance when the model is fully assembled, and with flying battery in position, should be approximately one-third back from the leading edge of the wing. If it is not, move the battery along the fuselage.

If there is not enough room and your weight distribution has come out slightly different, you must weight the nose or tail with a small weight, but the balance must be correct.

Glue a ¼ in. packing of balsa under the leading edge of the tailplane for preliminary tests. This may be reduced later.

Fig. 4 shows the ignition system and Fig. 5 the chassis construction of the 6 c.c. petrol model. It will be seen that the chassis is of the sprung type which permits the landing shocks to be absorbed, and in conjunction with the knock-off engine mounting makes the model reasonably crash-proof. The rubber band method of securing the wings safeguards them against damage.

The wiring system is self-explanatory. Now choose a field, if possible, with a slight downward slope that leads directly into a slight wind. Try gliding the model by holding above the head and throwing direct into the wind. A straight forward steady throw is necessary, of reasonable but not excessive speed, into a moderate wind. Do not throw upwards. Throw straight, or only very slightly downwards like a dart.

If the model dives, reduce the block under the front. If the model noses up, give a little more under the front of the tailplane.

In this way get the glide perfectly flat, with nice wheel landings every time. Only slight variations of the C.G. position may be permitted to assist tail settings. If you have got your mainplane angle correct, there should be very little alteration of tail, etc., necessary to get the glide correct.

On no account try flying under power until the glide is correct.

Keep the fin set straight so that the model will glide straight after the power is off, and it will then not land whilst winding and banking and with one wing down, and so cause a cartwheel landing.

Do not alter these gliding settings on any account for power flight.

Alteration of climb and turn under power is done by tilting the thrust line of engine on this model. This is the only safe way.

Now choose a decent piece of grass, and as a safety precaution put a piece of $\frac{1}{16}$ in. packing in between the top of your engine mounting and the fuselage, to give temporary down-thrust.

Give three-quarter revs. on your tiny engine by controlling the ignition lever. Set the timer for 10-second hops, and give the model a slight push directly into wind. She probably will not rise. Reduce the down-thrust $\frac{1}{16}$ in. at a time until she does rise gently. Now try longer hops, and if the model tends to turn too rapidly, give opposite side-thrust to counteract. Make sure that you have no warp on either wing or fin.

"Cutting Tools for Engineers." By A. H. Lundy. 130 pages. Price 3s. 6d. Crosby Lockwood & Son Ltd., Stationers' Hall Court, London, E.C.4.

IN this book the author presents, in a clear and simple manner the principles and application of cutting tools used by engineers.

Whilst the needs of the engineering student and apprentice have been the primary consideration, the craftsman will find much that will benefit him. The book is well illustrated with practical diagrams.

"Jigs, Tools and Fixtures," By Philip Gates. Published by The Technical Press Ltd. 216 pages. Price 10s. net.

THIS is a practical book for the apprentice and man in the shop, and deals with the drawing and design of equipment for all modern machine tools. In this second edition, a chapter on materials, a subject closely related to jig, tool and fixture design, has been included. Altogether there are sixteen chapters, covering, amongst other subjects, Mechanical Drawing, Drill Jigs, Milling Fixtures, Chucks and Turning Equipment, Cutters, Gauges, Press Tools and Magnetic and Pneumatic Gripping. The author deals with the subject in a simple manner, covering at the same time as wide a field as possible. In addition to several photographic illustrations and line drawings, the book includes a large number of useful tables, and a six-page index.

"Modern Armaments." By Professor A. M. Low. Published by The Scientific Book Club. 274 pages. Price 2s. 6d. to members.

EVERYONE interested in armaments will find a mine of information on the subject in this new book by Prof. A. M. Low, who is an acknowledged authority on all types of modern armaments. The subject matter is dealt with in a simple and popular manner, and is readily understandable to the ordinary reader. The book is divided into seventeen chapters covering, amongst other subjects, Explosives; Small Arms; Artillery; Chemical Warfare; Warships; Mines and Torpedoes; Tanks; In the Air; and Parachutes. Amongst a host of other details the reader is told about the secret of manufacture of big guns; how machine guns and other automatic guns and rifles work; all about explosives and ammunition; how gases and incendiary bombs are made, the development and manufacture of tanks and armoured cars; all about battleships and aircraft carriers; the mass production of aeroplanes; and how that wonderful apparatus, the predictor, works. There are also interesting chapters on the adaptation of weapons to peace time uses, such as the employment of gas for destroying rats, and other vermin. This book, which is illustrated with several fine photographic reproductions, can be recommended to all well-informed persons who are anxious to keep up-to-date with the latest scientific developments in connection with armaments, and to learn how some of the modern instruments of warfare may be turned to good use in peace-time occupations.

"Standard Screw Threads and Twist Drills." By George Gentry. Price 1s. 6d. Published by Percival Marshall & Co., Ltd., 60 Kingsway, W.C.2.

IN this enlarged edition of the above book the author has brought the section on screw die tackle up to date, and further illustrated matter has been added explaining the construction of the various dies and screw-plates now on the market. Six comprehensive tables are included covering Whitworth Screw Threads, British Association and Metric Screw Threads, Cycle Standard Screw Threads, "V" Standard and U.S. Standard Threads, Standard Twist Drills and Drill Sizes in 1/1,000 up to 1/16 in.

"This Strange World." By A. E. Trueman. Price 2s. 6d. Published by the Scientific Book Club, 111 Charing Cross Road, W.C.2. 240 pages.

IN this book, written by an eminent British geologist are sketched the main outlines of the history of the earth. It deals with geology, which is pre-eminently the layman's science, for many of the facts discussed can be verified by any intelligent observer without the use of special apparatus. But while it has been prepared for the reader unacquainted with the subject and contains few technical terms, it describes the results of many recent discoveries and shows the importance to the ordinary citizen of a knowledge of the occurrence of raw materials, the bulk of which are found within the crust of the earth.

"Metal Working Tools." By Percival Marshall. Published by Percival Marshall and Coy. Ltd. 84 pages. Price 1s. 6d. net

THIS useful handbook is intended as a guide to persons desirous of taking up mechanical work as a hobby, and who are about to make their first acquaintance with metal working tools. The various kinds of hand-tools commonly used for light engineering work are illustrated and described, and many hints are given as to the correct methods of using such tools. The final chapter deals with the equipment of a small workshop.

"Micrometer, Slide Gauges and Calipers." By Alfred W. Marshall and George Gentry. Published by Percival Marshall and Coy. Ltd. 80 pages. Price 1s. 6d. net.

PROFESSIONAL and amateur mechanics, as well as apprentices and students will find this small handbook of considerable interest and practical help. The subject matter deals chiefly with small measuring instruments of the caliper and micrometer class, and the book is written in simple language for the instruction of practical workers who have an intelligent interest in these instruments, and wish to use them to practical advantage. In this revised and enlarged edition, account has been taken off all modern developments in engineering workshop practice, and the design of measuring instruments. The book is well illustrated.

TOOLMAKING AND TOOL DESIGN—7.

The Principles and Methods of Making Press Tco!s, Jigs, Gauges and Fixtures

By W. H. DELLER

Previous Articles in this Series appeared in Nos. 61, 63, 64, 65, 67 and 76.

Mounting Fixtures on a Lathe

WHERE a fixture is intended to be mounted on the face-plate of a lathe it is usual to provide a means of location to ensure that the fixture will be correctly positioned without having recourse to the use of measuring instruments each time it is fixed in place.

The common method of doing this is by having a shallow recess in the face-plate as

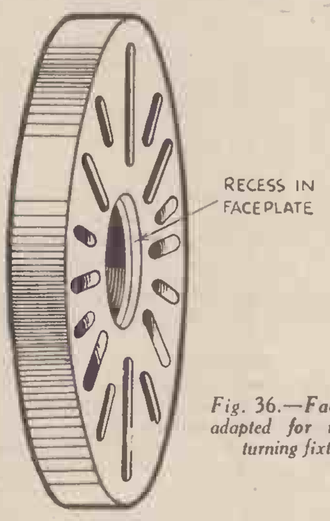


Fig. 36.—Face-plate adapted for mounting turning fixtures

illustrated in Fig. 36. As this procedure will affect the usefulness of the plate for general work it is better if a spare face-plate is so treated. Such a plate need not be slotted, a plain one will serve the purpose admirably and most fixtures can be designed in such a manner that the fixing holes can pick up a pair of studs screwed into the plate. The fixture can, of course, be made complete to screw on to the nose of the lathe, but this will probably involve the inclusion of a balancing medium which will mean increasing the total weight unnecessarily. Smaller fixtures of a compact nature might well be so mounted, but the less cumbersome method usually will be to fit them with a taper shank, to fit into the nose of the lathe, and provided with a draw bar for extra security.

Mounting Fixtures on Slotted Tables

The usual method of locating a fixture on machines having slotted tables is seen in Fig. 37. The short keys at either end are seated in shallow keyways, cut in line, and secured with screws. Where the base of the fixture is short, the key can run the whole length of the distance between the bolt slots. The keys should be made to fit the slots with a clearance of about .001 ins. A heavy fixture might require to " pick up " two or more slots for purposes of bolting down rigidly, but it is not necessary to provide keys for each slot. It may be that for the performance of a second operation the same fixture would suffice if turned at 90 degrees on the table. In this case additional lugs and keyways would be provided in the appropriate position and the keys transferred between the operations.

Circular tables for use in conjection with horizontal or vertical milling machines are centrally counter-bored as on the face-plate illustrated, thus enabling fixtures provided with male registers to be located centrally thereon.

Turning Fixtures

A turning fixture suitable for mounting the bend casting (see Fig. 30) while performing the second operation, consisting of turning, facing and screwing, is illustrated in Fig. 38. This fixture is an angle bracket, having a male register on the back face machined to a " push fit " in the female register in the face-plate of the lathe that it is intended to be used upon.

The centre distance of this register from the work locating surface is made to correspond to the requisite height from the surface of the previously machined face to the centre of the screwed portion. A hole is bored in the horizontal surface of the fixture (as drawn) central with the back register. This hole receives the spigot on the

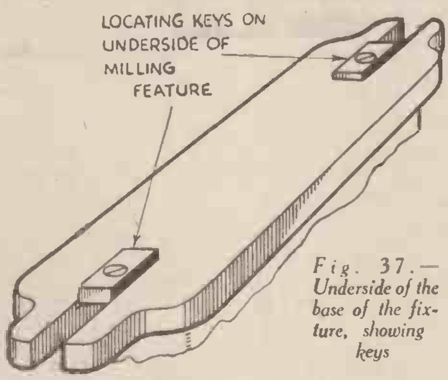


Fig. 37.—Underside of the base of the fixture, showing keys

bottom face of the bend and the fit should be such that there is no slackness, but at the same time the work must be easily inserted and removed.

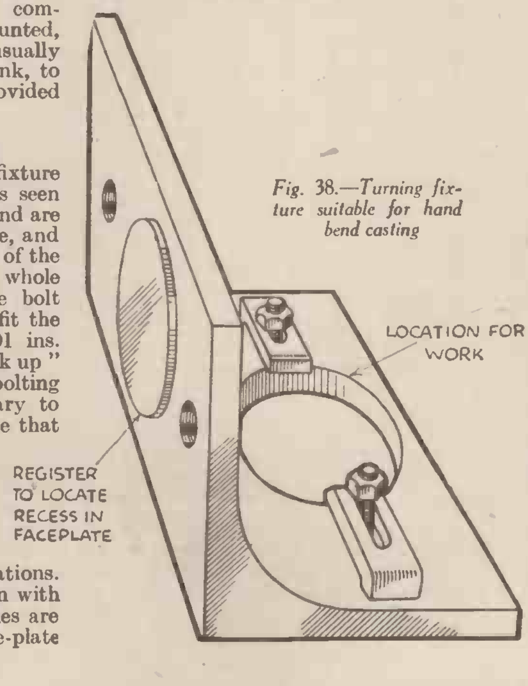


Fig. 38.—Turning fixture suitable for hand bend casting

When the fixture is made from a casting, there is no need to machine the entire surface about the hole, but provision can be made on the pattern to leave a shallow boss round the hole which is faced to provide a seating for the bottom flange. If this is not done the casting may have a shallow counterbored portion slightly larger than the diameter of the work. The mouth of the hole is slightly chamfered to provide an easy entry and to ensure that the flange will seat positively.

A pair of sliding clamps having " heels " afford the means of securing the work in position. The studs should be so positioned, and the slots in the clamps made long enough, to permit their being slid towards the respective edges of the fixture to enable the work to be inserted or removed without taking the clamps from the studs. Light coil springs should be interposed on the studs between the face of the fixture and underside of the clamps.

A fixture of this type may be built from bright mild steel plate, the back being attached to the base by means of flush fitting " Allen " or similar cap screws and dowel pins, and the webs attached in the same manner. Where the work is of a light nature or of small proportions and the fixture consequently of small dimensions a shank made to fit the nose of the lathe and fitted into the back of the fixture could form an alternative method of mounting on to the machine.

A fixture of this description may be modified to handle a variety of similar work. This might involve alterations in the clamping method described, and perhaps the

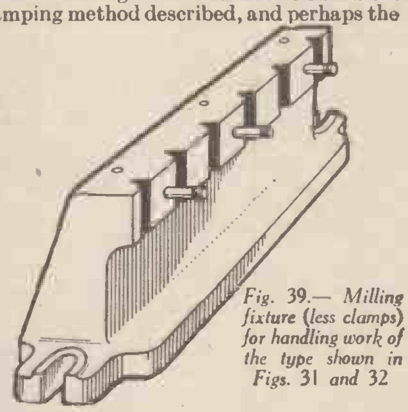


Fig. 39.— Milling fixture (less clamps) for handling work of the type shown in Figs. 31 and 32

inclusion of locating strips to correctly line up flat machined edges on the work.

Milling Fixtures

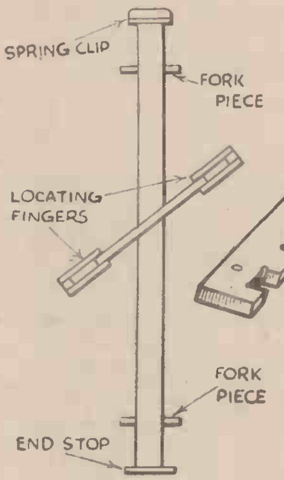
A milling fixture suitable for handling the type of work illustrated in Figs. 31-32 is seen in Fig. 39. This is made from a casting, the back of the vertical portion being heavily webbed to provide the necessary rigidity. The casting is machined on the base and provided with keys as already described in line with the holding-down lugs. The top face of the casting and the side square with it are machined, and the vertical surface, in which the Vees are cut, overhangs the remainder of the vertical portion so as to provide ample clearance for parts having long shanks. In many shops the type of work which this fixture is intended to handle is of a constantly recurring nature. Therefore in designing such a fixture it is advisable to make its scope of application to cover as wide a range as possible.

The Vee slots are, of course, cut to an included angle of 90 degrees and are of equal depth. A stud is placed between each pair of slots so that the two adjacent parts when in position are bridged by a single flat clamp having a central hole. To assist in reducing the time required for loading and unloading, the centre hole in the clamps may be slotted out to one side, or, where the centre distance between the Vees in the fixture will permit, "keyholed" to allow the clamp to be removed while the stud nut remains in position. In arranging the centres of the Vees care should be taken to keep them as close together as possible in order to reduce idle cutting time to a minimum.

The work illustrated in Fig. 32 would be machined from square bar material and the milling performed in two operations. With such work, therefore, it is necessary to make some provision on the fixture to position the parts to ensure that the milling is correct in relation to the sides of the bar. It is presumed, of course, that the shanks of the parts will be machined, with reasonable accuracy, centrally on the bar, as it is from the sides that the location will be taken. A hardened steel "comb-plate" as illustrated in Fig. 40 is attached to the top of the fixture for this purpose with bolts or screws, and further correctly maintained in position with regard to the Vee slots by dowel pins. The slots in the comb plate are made to suit the width of the bar material used for the manufactured parts, and there should be a fair gap left at the bottom of the slots for swarf clearance. For the same reason the comb portion could, with advantage be raised, by means of a step at the back, to facilitate cleaning.

Broaching Fixtures

The greater proportion of broaching work consists of cutting splines, squares or keyways in circular blanks and, therefore, the necessary fixtures are of a simple nature. An adapter which will enable the part to be centralised in relation to the axis of the broach is all that is usually required. When, however, the work is similar to that shown in Fig. 33 it is necessary to make provision for locating from the smaller boss of the lever.



Figs. 40 and 41. — (Above) Comb plate for use in conjunction with fixture. Fig. 39.—(Left) welding fixture

Surface broaching is an operation of an entirely different character and work to be handled by this method will demand provision of fixtures similar to those used for milling operations.

Fixtures for Assembling

A fixture for handling the welding assembly illustrated in Fig. 34 is shown diagramatically in Fig. 41. Such a fixture could be built up on a flat base but the construction would be simplified by building up on a round bar. A bar of suitable proportions would be shouldered down and threaded at both ends, and stout sheet metal fork pieces drilled at the lower ends to pass over the larger diameter and the centre between the fork and the hole being such as to raise the washer, forming the flange, clear of the bar. This washer is located between strip steel fingers riveted to the ends of a U piece, which is welded at the base to the bottom of the bar in an appropriate position.

A piece of flat steel, drilled at one end and bolted to the shouldered end of the bottom bar, forms an end stop for the tube. The flat spring clip, the purpose of which is to maintain the end of the tube against the stop, is similarly attached to the opposite end. After the flange has been "tacked" in position on the tube, the assembly is lifted from the fixture for completion of the welding.

Mounting on the Fixture

The assembly illustrated in Fig. 35 might be handled in the following manner: after first drilling and taper pinning an end bracket to the tube, the partly assembled tube and bracket with the bell-crank lever, collars and remaining bracket in position will be mounted on the fixture. This will consist of a base plate provided with studs to suit the required centres of the brackets. After bolting down, the unpinned bracket would be drilled, taper-reamed and pinned. The bell crank lever could be positioned by a pair of blocks, or a slotted block, attached to the base plate, and the collars, having been drilled through one side prior to assembly, would be drilled through the tube and opposite side of the collar, reamed and finally pinned in place. A slotted shim which would subsequently be withdrawn might be placed between the boss of the lever and one of the collars, whilst pinning, to ensure a working clearance between the faces.

Launching Model Aeroplanes from a Model Boat

An Ingenious Idea that is Simple and Never Fails

THE mail carried by a liner to-day arrives at port several hours ahead of the ship. This is done, of course, by launching a mail-carrying aeroplane from the deck of the liner when she is still several hundreds of miles out at sea.

The model described herewith is adapted to work on the same principle. It consists of a model launch which is steam or electrically driven and provided with a landing deck (see Fig. 2). The launch should be very much larger than the 'plane so that there may be plenty of deck space for the take-off.

The Landing Deck

Plywood is a good material for the landing deck, which in the sketch extends from X to Y. If possible, it should reach a few inches beyond the bow of the boat.

The arm CK is shaped like a tuning-fork and works on a pivot at M. At K is a headless nail S, which fits into a corresponding hole bored in arm OP. E is a hook to which is attached a length of wire or thread connecting F. At G is a small pulley wheel. FH is a length of rubber of the kind used for model aeroplanes. R is a wooden wheel for winding FH, and is provided with a hole so that it can be turned with the finger. It will be seen that when the rubber FH is wound up tight the arm OP working on the pivot P will rise at O, and that CK will be held rigidly vertical by means of the nail S passing through the hole in OP. By pushing a bolt through the fingerhole in the winding wheel as shown, CK will remain in this position as long as required, providing FH is well wound.

The propeller of the 'plane is held and prevented from revolving by the prongs of the arm CK, as shown in Fig. 1. It will thus be seen that it is possible to fully wind the 'plane and place it unattended in position on the deck.

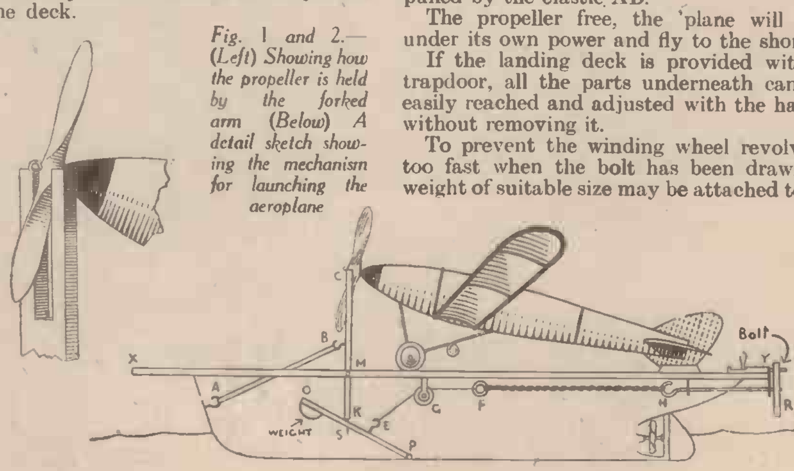


Fig. 1 and 2.—(Left) Showing how the propeller is held by the forked arm (Below) A detail sketch showing the mechanism for launching the aeroplane

Keeping the 'Plane in Position

Two small pieces of wood should be screwed side by side on the deck, with sufficient space between them for the tail of the 'plane to rest in, thus keeping it in position. The launch and 'plane are now ready for sailing.

When the engine has been started, the boat should be set against the wind and the bolt drawn from the winding wheel. The rubber FH then immediately begins to unwind itself, with the result that EF becomes slack, and through a weight at O the arm OP falls in a horizontal position. Through the nail S slipping out of its hole CK is released and falls level with the deck, pulled by the elastic AB.

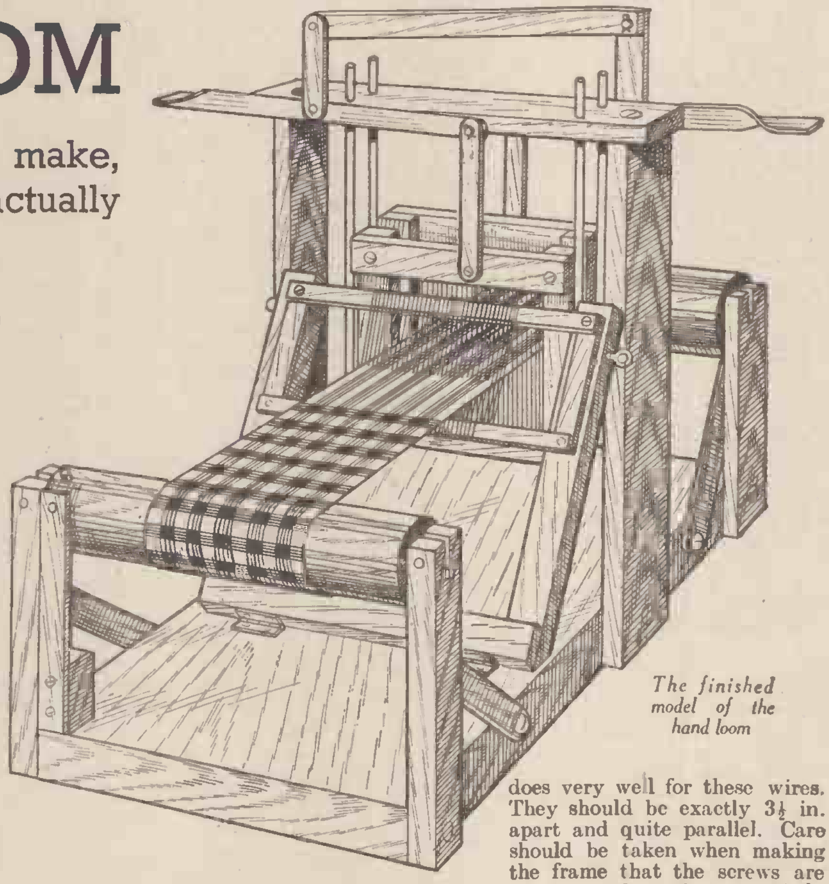
The propeller free, the 'plane will rise under its own power and fly to the shore.

If the landing deck is provided with a trapdoor, all the parts underneath can be easily reached and adjusted with the hands without removing it.

To prevent the winding wheel revolving too fast when the bolt has been drawn, a weight of suitable size may be attached to it.

A WORKING-MODEL HAND LOOM

This model is easy to make, simple to work, and will actually weave cloth



The finished model of the hand loom

A LOOM is often regarded as a somewhat complicated piece of machinery, but the model described is really quite simple to make from everyday materials and requires the use of only a modest set of tools.

The perspective illustration, Fig. 1, shows the construction of the complete main frame; when complete, the loom will weave plain as well as pattern cloth. The longitudinal or "warp" threads are wound on to the roller at the back and pass through the "healds" to the front roller. These rollers are called "beams." That at the back being the "warp beam." As the weaving progresses the finished cloth is rolled on to the cloth beam and the warp unrolled from the other.

Forming the Cloth

To form the cloth alternate threads of the warp are lifted or depressed to form a "shed" or wedge-shaped opening through which the shuttle is passed, leaving behind it the transverse thread or "weft." The weft is pressed tightly into place by means of a comb-like affair termed a "reed," after which the warps change over, the lower ones coming to the top, and vice versa, ready for the shuttle to lay the next thread or weft, thus building up the cloth thread by thread as the operation is repeated.

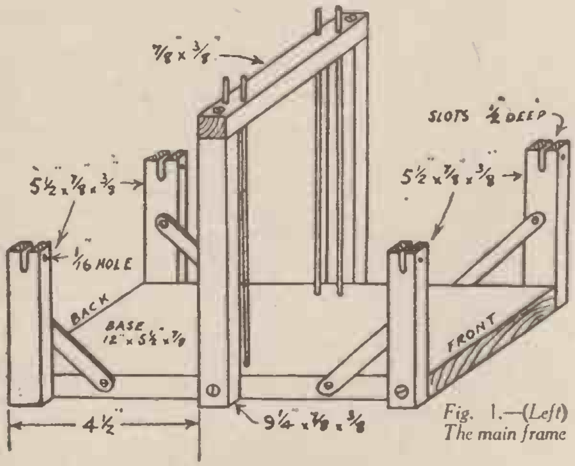


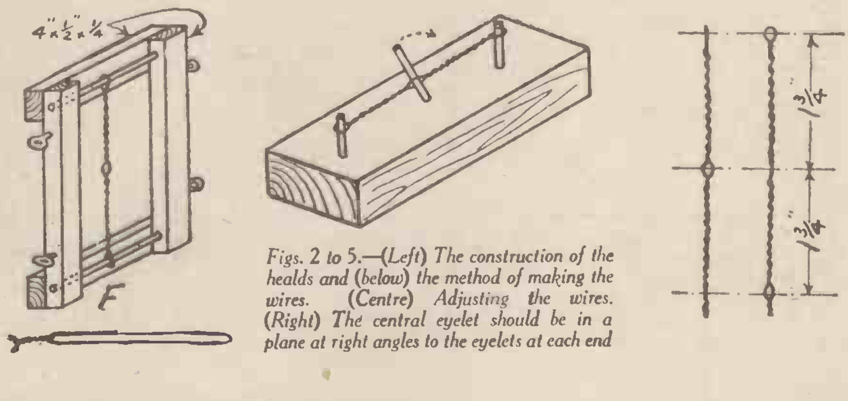
Fig. 1.—(Left) The main frame

Start by making the main frame, as shown in Fig. 1. The brass diagonal struts are necessary on the four corner-posts to prevent them from being pulled over by the tension on the warp, but there is no tendency to pull the central frame over, so it will suffice just to screw this up as tightly as possible. The four vertical rods inside the central frame are made of straight lengths of round brass or steel, $\frac{1}{8}$-in. in diameter; they are not fixed otherwise than by being a tight fit in the holes drilled for them at top and bottom. Each rod should be ¼ in. from its immediate neighbour and ½ in. from the wooden upright; let them project ½ in. above the top of the frame when fitted, so that they may be withdrawn by means of a pair of pincers when necessary. These rods form guides for the "healds" or frames which lift or depress the warp threads.

The Wooden Frame

Fig. 2 shows the construction of the healds, two of which are required. The wooden frame is of the simplest possible description, all the four pieces of wood are alike and are just screwed together, as shown, with tiny screws. A touch of glue on the corners before screwing together is an advantage. The horizontal wires are $\frac{1}{16}$ in. in diameter and a tight fit in their respective holes. A knitting needle does very well for these wires. They should be exactly 3½ in. apart and quite parallel. Care should be taken when making the frame that the screws are not put in a position where they are likely to get in the way of the $\frac{1}{16}$ in. wire. The screw eyes in the side members should be small ones; they have to slide up and down the vertical rods inside the central frame.

The wires to carry the warp threads should now be made; only one of these is shown in Fig. 2 to avoid confusion, but sixty are required, thirty for each heald. This will give us twenty warp threads per inch on a piece of cloth 3 ins. wide, and this provides the usual texture. The method of making the wires is shown in Figs. 3 and 4. Drive two nails about $\frac{3}{32}$ in. in diameter into a piece of wood, so that they are $3\frac{13}{32}$ ins. apart, centre to centre, and cut off the heads; then take a piece of wire about 9 ins. long, lay it round the two nails and twist up the end for several turns to form a long loop, as shown in Fig. 3. Now make another jig with two nails and a piece of wood exactly as before, except that the nails should be only 3½ ins. apart this time.



Figs. 2 to 5.—(Left) The construction of the healds and (below) the method of making the wires. (Centre) Adjusting the wires. (Right) The central eyelet should be in a plane at right angles to the eyelets at each end

Adjusting the Wires

Lay the loop on the new jig and put a short piece of 1/16-in. wire through the loop and twist the loop up by means of the 1/16-in. wire till all the slack is taken up, as shown in Fig. 4. Give one or two extra turns to make the wire nice and taut, but not enough to break it. It is better, perhaps, to twist one or two up until they break so as to get a good idea of how much twisting is required, then you can stop just short of the breaking point afterwards. When finished, the central eyelet should be in a plane at right angles to the eyelets at each end (see Fig. 5). Twist the wire in the same direction on both jigs, otherwise you may find yourself in difficulties.

The wire should be 28-gauge soft brass or copper, or 28-gauge enamelled copper electrical wire will do very well; leave about 1/4-in. of the twisted end on, as shown in Fig. 5; the rest may be snipped off.

Draw back the 1/16-in. wires on the healds and thread on thirty of the twisted wires; then push the 1/16-in. wires back into place; they should fit tightly in the wood. The twisted wires should be able to move about freely when fitted, so as to be able to take up their own position when the threads are in place. The healds may now be fitted to their guides in the main frame, with the horizontal wooden members outside.

Next, make the operating levers for the healds, as shown in Fig. 6. Two of these are required; they are just strips of 1/16-in. brass soldered together, the end being twisted to make a convenient handle.

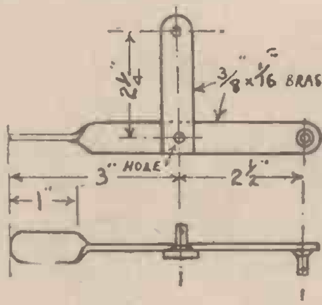


Fig. 6.—The operating levers for the healds

The Pivots

These are ordinary brass wood-screws, soldered on and the threaded part cut off, after which a 1/16-in. hole is drilled for a split pin. Screw the levers on to the top horizontal member of the main frame by means of a single screw which forms a pivot. One lever should be on the front at the left and the other on the back at the right, the inner end of each lever reaching to the centre line of the machine. Connect each inner end to its respective heald by means of a simple link like Fig. 7. The top end of this link goes on to the pivot soldered on to the lever and the bottom end is screwed to the top of the heald by means of a single screw, which must not be screwed right home.

Now make another link like Fig. 7, but long enough to connect the vertical members of the levers together; this link will have to be about 5 ins. long, but it will be better to measure off the exact distance on the job and make the link to suit. When this link is fitted and held in place by split pins, either lever will move both healds so that when one heald goes up the other goes down. Fix a screw into the side members of the main frame to limit the movement of the levers, allowing the healds to move 3/4 in. above and below the centre line, i.e., each heald has a total movement of 1 1/2 ins.

The Reed and Frame

Next make the reed and its frame, as shown in Fig. 8. The wooden part is simplicity itself; the bottom is cut off on a slant at each side to allow it to rock freely on its hinges. The metal frame is made from 3/8 in. by 1/16-in. strip brass, the horizontal members being 6 ins. long and the vertical ones 3 ins. long. Take the two horizontal members and clamp them together in a vice; then make a cut about 1/32 in. deep in the centre of the length with a fretsaw (don't use a hacksaw—it will be too wide), 1 1/2 ins. away on each side of the first cut (giving five nicks in all), then go on halving the distance between each until you have made sixty-five nicks altogether in a space of 3 ins. Separate the two pieces, solder up the frame at the corners and drill a hole at each corner for the fixing screws. Now get some 28-gauge hard brass wire (don't use soft copper or enamelled wire for this); if the wire is not hard when bought you can

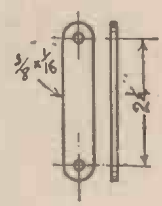


Fig. 7.—Details of the link

harden it by stretching it; fix one end of the wire by twisting it to the frame, then wind it over and over the frame, one wire in each nick, until all the nicks have a wire in them and secure the end of the wire temporarily. Wind the wire with moderate tension only; if wound too tightly the frame will bend

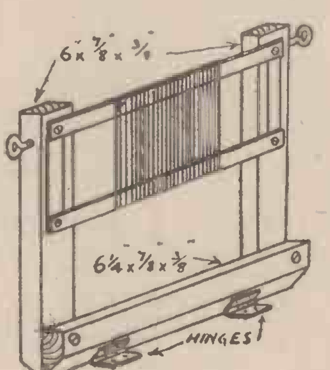


Fig. 8.—The reed and its frames

inwards and the wires first put on will be found very slack. Now solder all the wires firmly to the frame.

Next cut the wires at the back, thus leaving sixty-five single wires, all parallel, and stretched across the frame. Screw the frame on to its wooden support and fix the hinges on to the baseboard halfway between the main frame and the supports for the cloth beam. The screw eyes are for use as handles.

The "Beams"

The "beams" are made from four pieces of broomstick 1 in. in diameter, as shown in Fig. 9. The spindles are made from nails with the heads cut off. You will find it very difficult to get the wood true on the spindle, if you drive the nail in without special precautions. A good method is to mark off the centre carefully and drill a hole of the same diameter as the nail about 1 in. deep. Ask an assistant to watch the drill to make sure you are holding it upright. The drilled hole then forms an effective guide for the nail which should be driven in about 1/2 in. further to fix it firmly.

For the cloth beam drive in eight small brads and cut off the heads, leaving 1/8 in. projecting, as shown in Fig. 9. This provides a simple form of ratchet arrangement, the brads engaging a hole in a flat brass spring which can easily be made.

A piece of strong tape 3/4 in. wide is tacked along one edge only to the round wood, as shown in Fig. 9.

The warp beam is the same as the cloth beam except that the tape is tacked along the outer edge and, instead of the eight brads, a single round-head screw is fitted.

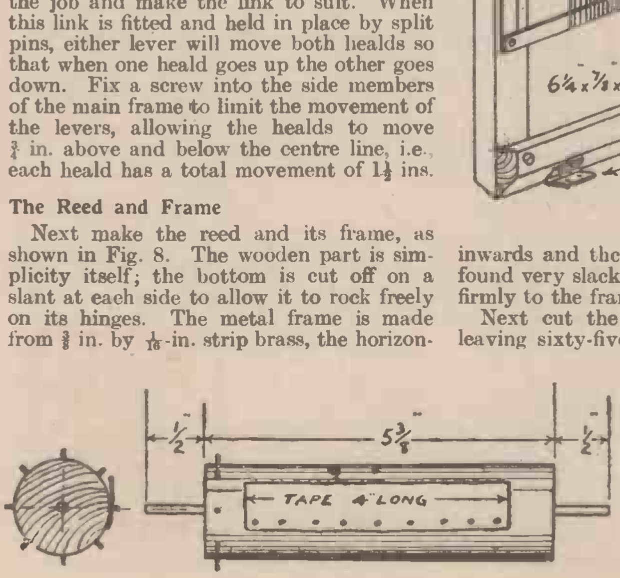
A rubber band is hooked over the screw eye in the baseboard to provide tension on the threads.

The only item now to be made is the shuttle, which is illustrated in Fig. 10. This is best cut out of a piece of bone about 1/8-in. thick, though 1/8-in. fretwood will do quite well.

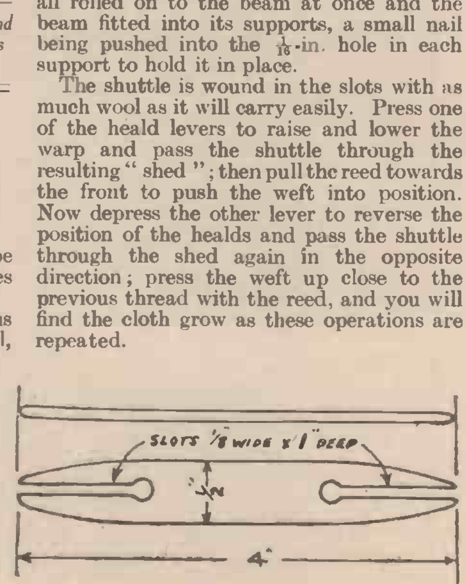
Weaving

Ordinary darning wool is good material to weave on this loom. The warp beam is fixed, temporarily, about a yard behind the machine and the wool is stitched on to the piece of tape of the cloth beam, threaded through the reed, then through the central eye in one of the twisted wires of the front heald and stitched on to the tape of the warp beam. The second thread passes through the next space in the reed, but is threaded through an eye in the back heald instead of the front one. Alternate threads go through an eye in the front heald and the threads between go through an eye in the back heald. The warp threads are then all rolled on to the beam at once and the beam fitted into its supports, a small nail being pushed into the 1/16-in. hole in each support to hold it in place.

The shuttle is wound in the slots with as much wool as it will carry easily. Press one of the heald levers to raise and lower the warp and pass the shuttle through the resulting "shed"; then pull the reed towards the front to push the weft into position. Now depress the other lever to reverse the position of the healds and pass the shuttle through the shed again in the opposite direction; press the weft up close to the previous thread with the reed, and you will find the cloth grow as these operations are repeated.



Figs. 9 and 10.—(Left) Details of the "beams." (Right) The shuttle



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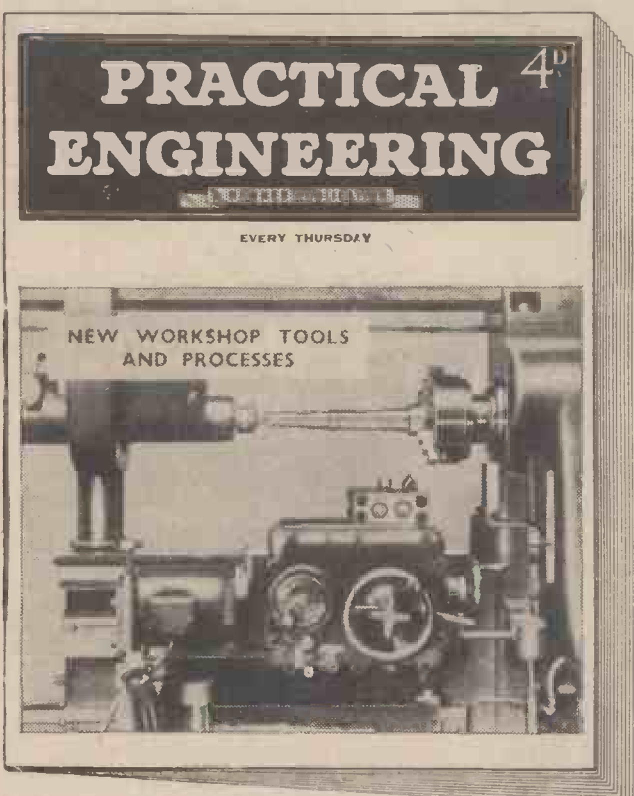

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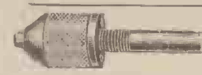

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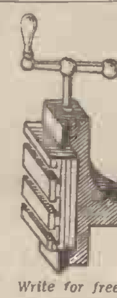

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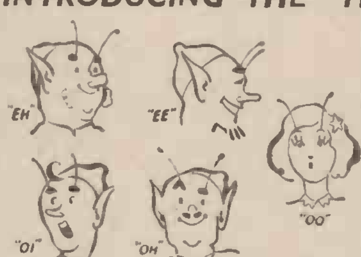

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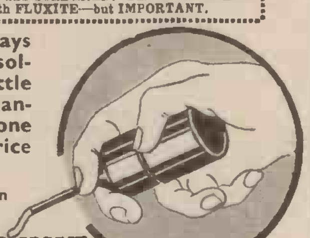

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Further Constructional Details of the Cylinders and Valve Gear

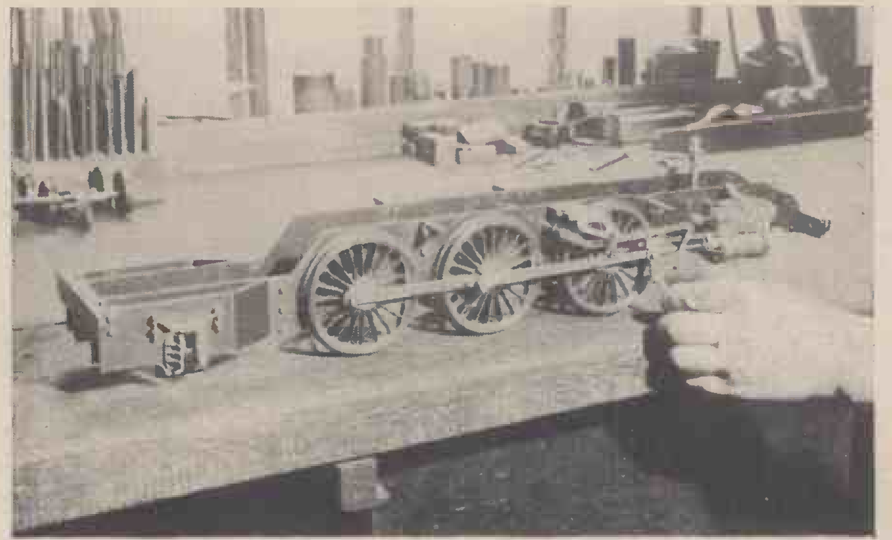


Fig 19.—Engine main frames, with driving wheels, cylinder and valve gear assembled on one side

BEFORE continuing with the details of construction, it would be as well at this stage to study the full specification of materials, castings and fittings for this locomotive, which is given on the following page. All these parts are obtainable from Bassett Lowke, Ltd. Only the castings, etc., necessary for the particular part of the work in hand need be purchased at a time. Other parts can be obtained as the work proceeds.

Engine Cylinders

The cylinders, which are of standard type, 11/16 in. bore and 1 in. stroke, are turned from gunmetal castings. It will be noticed, with reference to Fig. 21, that the port face of the cylinder is inclined, the slide valve being of the ordinary D pattern.

Each cover is marked out and drilled for six 3/32 in. fixing bolts. The steam inlet in the valve-chest cover is drilled and tapped 3/16 in. for the steam pipe, and the exhaust outlet is tapped 7/32 in. for the exhaust pipe. The piston rods, of 5/32 in. diam. steel, are cut off to the length required (see Fig. 20), the ends being screwed 40 threads per inch for screwing into the pistons. Each cylinder is secured to the frames by four 1/8 in. hexagon-headed screws.

The valve rod, which is 3/32 in. diam., is turned down at one end, and screwed for part of its length for the valve-adjusting nut, as shown in the drawing. The crossheads, after machining, are drilled and forced on the ends of the piston rods, and then pinned.

The exhaust pipe, of inverted-T type, is formed from ¼ in. diam. copper tube, the ends being screwed for fitting into the exhaust outlet of the cylinders. The discharge end of the exhaust pipe is fitted with a push-on nozzle. (See Fig. 15.)

Each crosshead guide-bar, of ¼ in. by 1/8 in. steel, is drilled at one end for taking a steel stud for fixing it to the piston-rod stuffing box on the front cover. (See Fig. 21.)

The valve-spindle crossheads are made from ¼ in. steel, and are slotted and drilled, as shown in Fig. 21, which also gives details of the various parts for the valve motion, all of which are of steel.

Driving Wheels

All the engine driving wheels are quartered, and the cranks set at 90 degrees. An eccentric (No. 3) having a bore of 5/16 in. and a stroke of 3/16 in., is fixed to the main driving axle for driving the boiler feed pump (No. 2). The pump assembly, and the pipe connections, are shown in Fig. 24.

The trailing side-frames, with dummy springs and hornblocks attached, are fitted to the main frames, with 3/32 in. bolts. (See Figs. 6 and 9). The six footplate supporting brackets are cut from 3/16 in. flat brass, drilled for lightness, and fixed to the main frames by 3/32 in. set screws. These brackets are clearly seen in Fig. 12. which also shows the driving wheels, cylinder, coupling rod, and valve gear assembled on one side of the engine main frames.

Coupling Rods

The coupling rods are machined from German silver castings. They are cleaned up to the sizes required, and milled on the faces. This is done to prevent rust, and to give a more pleasing appearance.

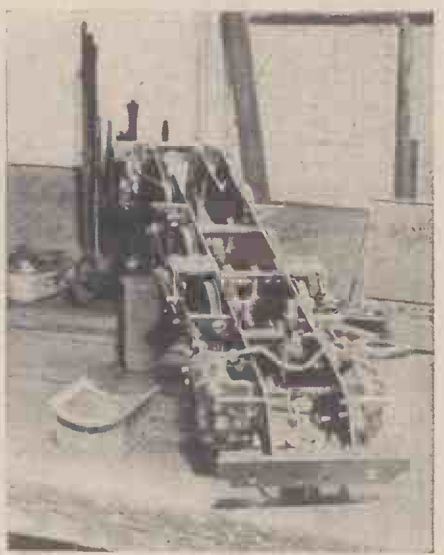


Fig. 23.—This view of the engine chassis shows the steam and exhaust pipe connections, feed pump, and footplate brackets

Gunmetal bushes are fitted to the main

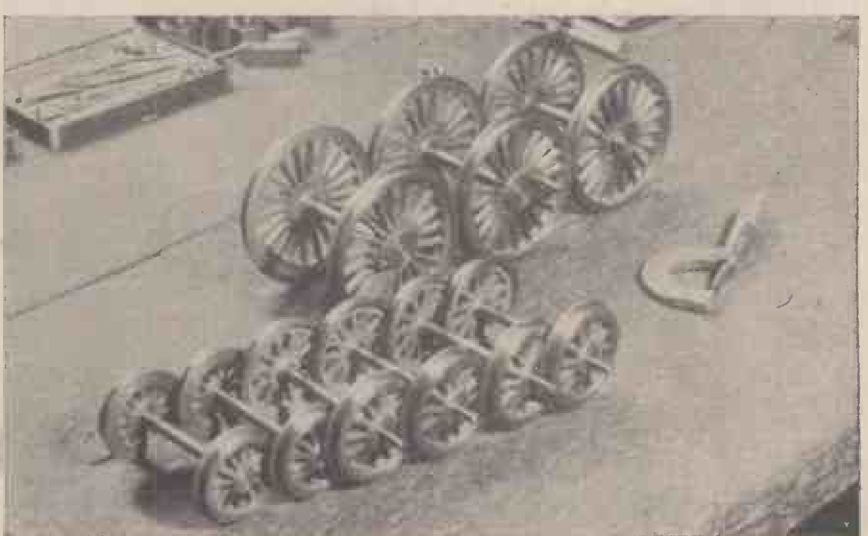
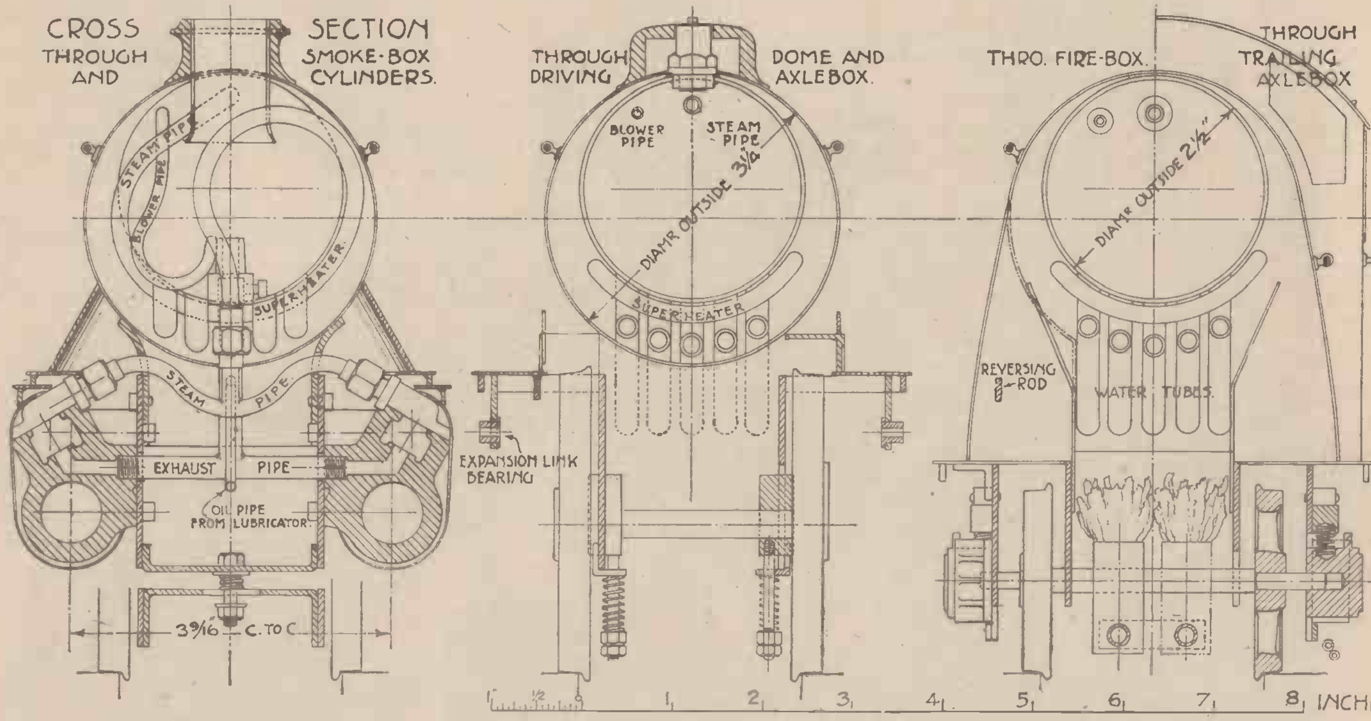


Fig. 22.—The finished engine and tender wheels on their axles



Figs. 15 to 18.—Cross sections through cylinders, boiler and firebox, and rear elevation of cab fittings

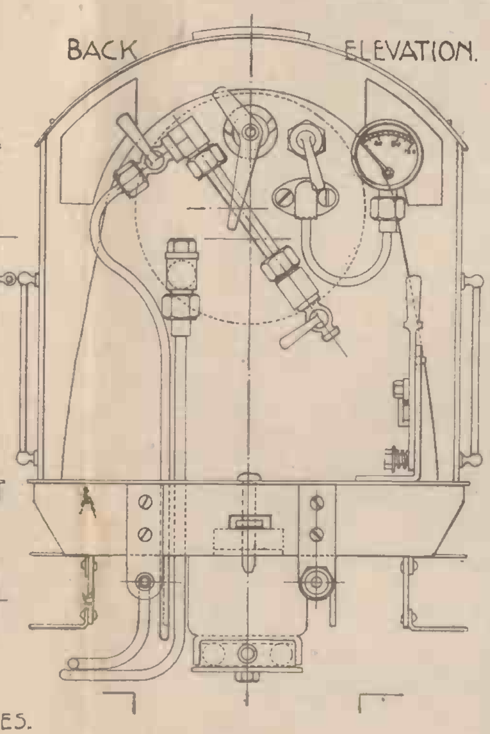
frames for the reversing shaft, in a central position, as indicated in Fig. 6. The motion brackets are built up from brass or gunmetal (or castings may be used) and they are fitted with phosphor bronze trunnion bushes. These are turned from rod, and are forced in place, and soldered. The brackets are then attached to the main frames by set screws. (See Figs. 12 and 13.)

A bracket to hold the axle-driven pump is made from 1/16 in. brass, bent to the same width as the frames, and fixed in place with countersunk screws. This bracket is seen just in front of the reversing shaft in Fig. 6. The pump is attached by 3/32 in. set screws.

Returning to the cylinder, two 1/8 in. male-end unions are used for connections to the steam pipe, and a No. 2 male end

MATERIALS, CASTINGS and FITTINGS for the ½-in. SCALE "FLYING SCOTSMAN"

STEEL PLATE			
1/16″ Engine main frames	2	pieces	22½″ × 2⅝″
" bogie frames	2	"	4¾″ × 1¼″
" rear outside frames	2	"	5½″ × 2″
Tender frames	2	"	13″ × 2″
Bogie stretchers	2	"	3¼″ × 1½″
Spirit burners support	1	"	2¾″ × 1¾″
Reversing quadrant	1	"	2½″ × 1¼″
Valve gear links and rods, reversing rods and sundry parts	1	"	13½″ × 2″
1/32″ Inner firebox	1	"	13″ × 2¾″
STEEL ROD, ROUND			
5/16″ dia. Coupled axles	1	"	10″ long
¼″ dia. All other axles	1	"	28″ "
Drawbar pins	1	"	3″ "
5/32″ dia. Reversing shaft	1	"	4½″ "
STEEL FLAT STRIP			
¼″ × ⅛″ Slide Bars	1	"	5½″ "
SHEET BRASS			
1/32″ thick—			
Boiler casing	1	sheet	19¼″ × 11″
Firebox back	1	"	4½″ × 4½″
" Throat plates	1	"	3″ × 2″
Smokebox Front	1	"	3¼″ × 3¼″
" door	1	"	2⅝″ × 2⅝″
Cab sides	2	"	3¾″ × 3⅛°
1/32″ thick—			
Cab roof	1	piece	5¾″ × 4″
Cab front	1	"	4¾″ × 4¾″
Footplating	2	"	24″ × 1½″
" side plates	2	"	5⅛″ × 1⅜″
" front and back plates	1	"	5″ × 2″
Tender tank sides	2	"	13¼″ × 4″
" " back			4¾″ × 4½″
" " front	1	"	4¾″ × 3½″
" " bottom	1	"	13½″ × 5″
" " top	1	"	13″ × 4¾″
" partition	1	"	4¾″ × 4½″
Footsteps and sundry parts	1	"	7″ × 2″
Vestibule Coupler	1	"	10½″ × ⅝″
" "	1	"	4¼″ × 2⅛″
" "	1	"	4⅛″ × 1⅝″
" "	1	"	2⅛″ × 1¼″
1/16″ thick—			
Expansion link brackets, hornstays, etc.	1	"	4″ × 3″
Pump cross stretchers	1	"	3″ × 1¼″
Spirit sump stretchers	1	"	4″ × 1¼″
3/32″ thick—			
Cab roof ventilators	1	piece	1½″ × 1½″
3/16″ thick—			
Expansion link bracket supports	2	"	1 3/16″ × 1 1/16″
BRASS BAR			
⅜″ × ⅜″ Coupled axleboxes	1	"	6″ long
SQ. BRASS ROD			
⅜″ × ⅜″ By-pass	1	"	1¼″ "
ROUND BRASS ROD			
⅜″ dia. Engine frame stays and reversing shaft bushes	1	piece	5″ long
STRIP BRASS			
⅛″ × 1/64″ Boiler Binding	4	"	8″ "
BRASS TUBING			
1″ dia. Spirit sump and Lubricator	1	"	3¼″ "
⅞″ dia. Chimney petticoat	1	"	1½″ "
9/16″ dia. Spirit Burners	1	"	12″ "
¼″ dia. " "	1	"	10″ "
5/16″ dia. " "	1	"	1½″ "
BRASS ANGLE			
1/16″ × ⅜″ × ⅜″—			
Hornstays and tender tank angles	1	"	12″ "
1/16″ × ¼″ × ¼″—			
Tender tank and frame angles, etc.	4	"	8″ "
Firebox angles	2	"	2″ "
BRASS STRIP			
3/16″ × 1/16″—			
Footplate valance	2	"	24″ "
COPPER TUBING			
2½″ dia. Boiler shell	1	"	16¼″ "
¼″ dia. Water tubes	5	"	17″ "
Exhaust pipe	1	"	4½″ "
3/16″ dia. Steampipe and superheater	1	"	60″ "
Pipes in tender etc.	1	"	20″ "
⅛″ dia. Water delivery (tender)	1	"	36″ "
Water (engine)	2	"	18″ "
Oil and steam lubricator	1	"	30″ "
Blower pipe	1	"	20″ "
BRASS WIRE			
1/16″ dia. Handrals	2	pieces	18″ long
" "	2	"	12″ "
HALF ROUND BRASS			
3/32″ wide—			
Tender and cab beading	5	"	16″ "
IRON CASTINGS			
Driving and coupled wheels	6	"	H60
Trailing and tender wheels	10	"	H61
Bogie wheels	4	"	H56
GUN METAL CASTINGS			
Buffer Beams	4	"	
Axleboxes, trailing and tender	10	"	
Axleboxes, horns and tender	20	"	
Springs (dummy)	10	"	
Splashers	6	"	
Boiler ends, 2½″	2	"	
Chimney	1	"	
Dome	1	"	
Dummy safety valves	2	"	
NICKEL OR GERMAN SILVER			
Coupling rods (front)	2	"	
" " (back)	2	"	
Connecting rods	2	"	
FITTINGS			
Cylinders, r. & l. h.	1	pair	A2
Pressure gauge	1	piece	¾″
Water gauge	1	"	91/1
G.M. Union cocks	3	"	114/1
Straight nose cocks	1	"	11/0
Gun metal unions, ⅛″	3	"	24/1
" " " 3/16″	1	"	24/3
Check valve	1	"	115/1
Regulator patt. C.	1	"	1468/2
Blower valve	1	"	1500/1
Pad for pressure gauge pipe, ⅛″	1	"	
Safety valve	1	"	144/1
Buffers	4	"	152/1
Handrail knobs, short pattern	2	"	No. 2
Axle driven pump, horizontal with eccentric	1	"	No. 2
Tender handpump	1	"	1726/2
Spirit needle valve	1	"	268/0
Brass filling screw, ⅜″	1	"	119/1
" " " ¼″	1	"	No. 2
" filling plug (push in), ⅝″	1	"	52/2



connects the superheater to the steam pipe. (See Fig. 15.)

The smoke-box saddle is fixed between the main frames with four 3/32 in. screws.

Footplating

With regard to the footplating, this is cut out of 1/32 in. sheet brass, and bent to shape with 1/16 in. brass beading soldered on. The curved front portion is cut out from 1/16 in. sheet brass, to the shape shown in the side elevation of the finished engine, Fig. 4. It is fixed in place by 3/32 in. screws.

Reversing Lever and Quadrant

The reversing lever is turned and filed from a piece of ¼ in. diameter mild steel rod, to the shape and dimensions given in Fig. 20. It has a stop pin, just below the handle, for engaging with holes drilled in the quadrant, as indicated in the drawing.

The quadrant, which is cut from 1/16 in. steel plate, is filed to shape, the lower part being bent at right angles for screwing to the footplate on the right-hand side of the cab, flush with the rear edge of the footplate (see Figs. 4 and 18).

For the reversing rod, ¼ in. by 1/16 in. steel strip is used, the rear end being upturned and drilled 3/32 in. to take the screw on the reversing lever. The other end of the rod is drilled for attaching to the cranked end of the reversing shaft.

Spirit Burners

At this stage the spirit burners, and

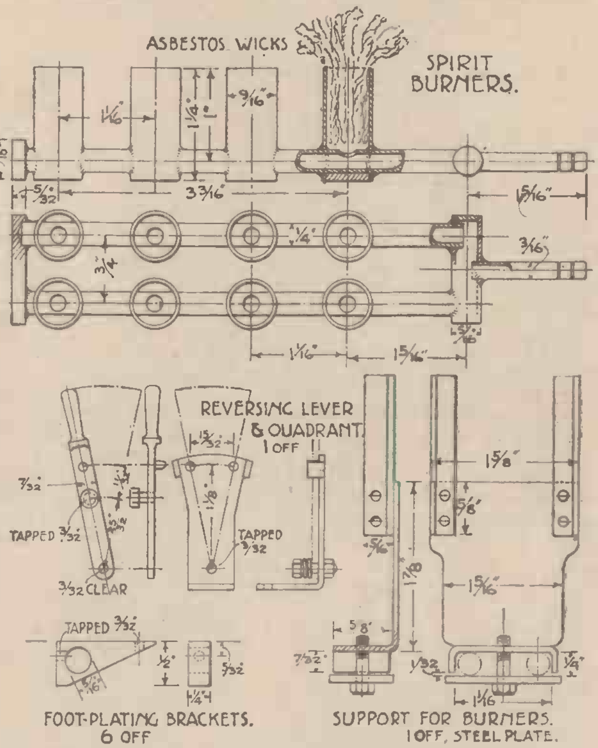


Fig. 20.—Details of spirit burner, supporting bracket, and reversing lever and quadrant

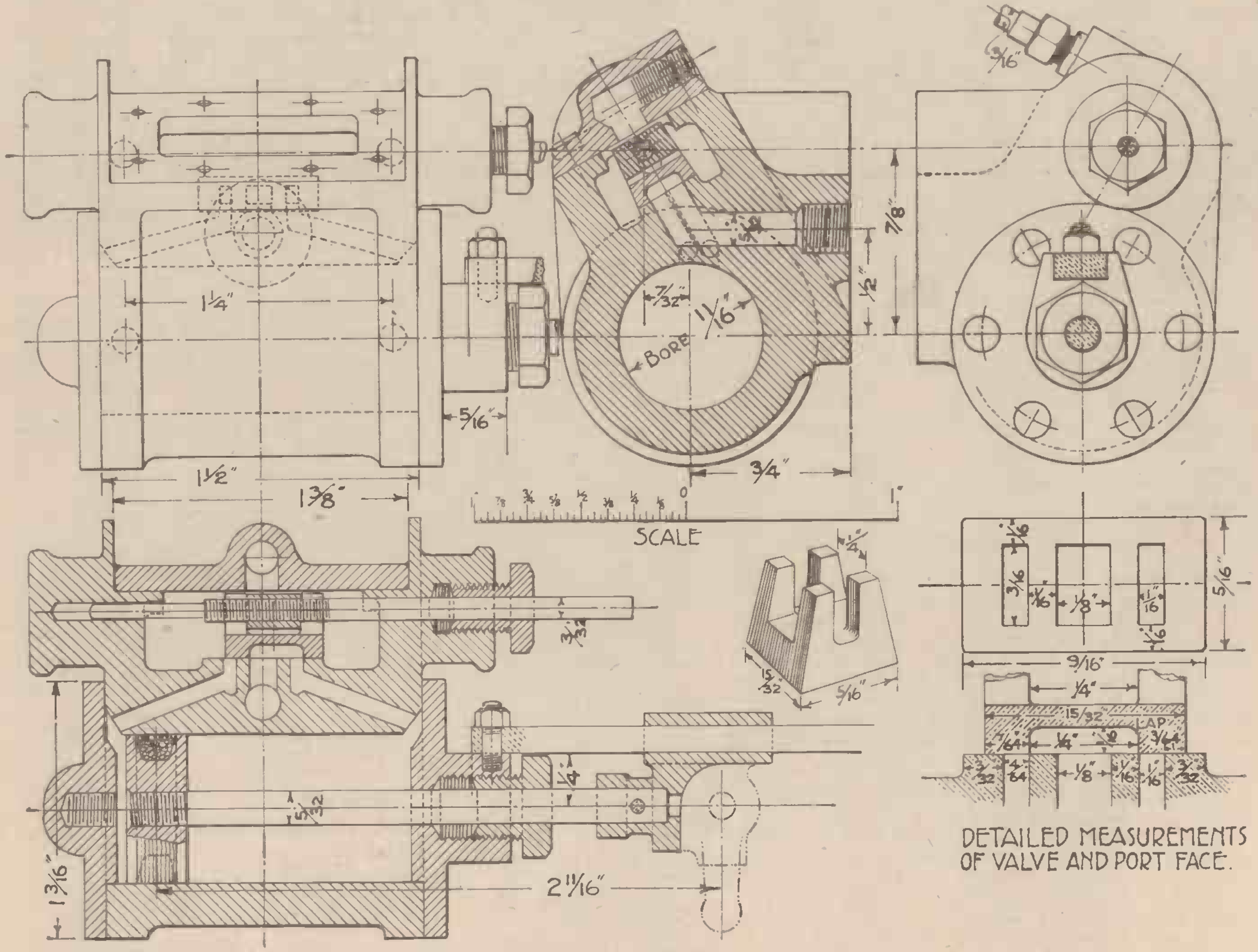


Fig. 21.—Details of cylinder, crosshead and slide-valve

supporting bracket can be taken in hand. It will be seen by reference to Fig. 20 that there are eight wick tu s, and these are cut to the length indicated, from mandrel drawn brass tubing of 9/16 in. outside diameter. Holes $\frac{1}{4}$ in. diameter are drilled through the lower ends of the tubes, diametrically opposite, to take the supply pipes. In the top wall of these pipes 1/8 in. diameter holes are drilled, spaced 1 1/16 in. apart, and these holes come in the centre of the wick tubes when the latter are silver soldered in place. The bottom of each tube is plugged with a brass disc, also silver-soldered in place.

The connecting T-piece at the rear end of the burner tubes is made up with two pieces of tubing, as shown, the front ends of the tubes being plugged with a brass strip, silver-soldered on.

(To be continued)

CORRECTION

Owing to a draughtsman's error, the drop in the main frames at the rear end was given as $\frac{3}{8}$ in. in Fig. 6 (February issue) just below the rear main axle box keep. This dimension should be $\frac{7}{16}$ in., giving an overall width of $2\frac{9}{16}$ in. for the main frame.

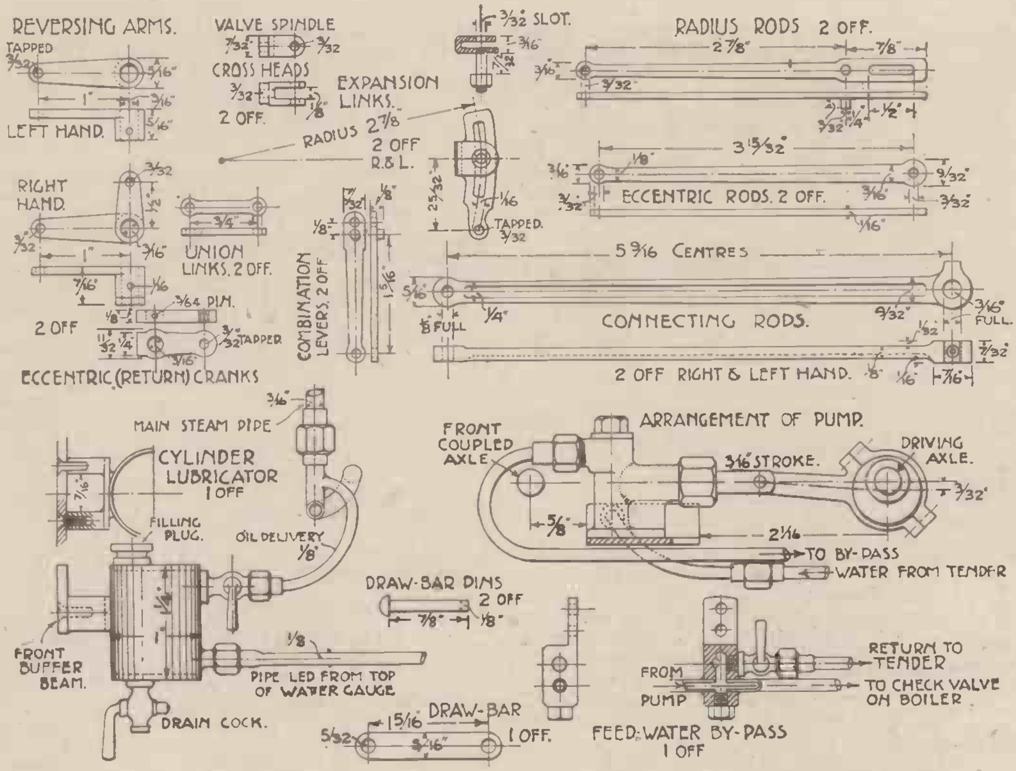


Fig. 24.—Details of valve gearing, connecting rods, boiler feed pump, and displacement lubricator

THE VACUUM FLASK

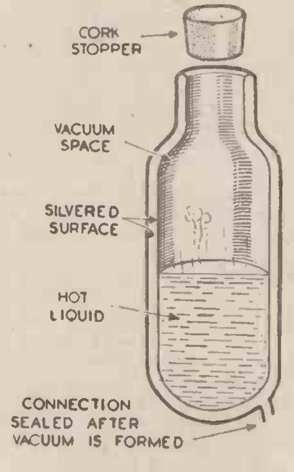
AT first an invention devised for laboratory use, the vacuum flask (or "Thermos" flask, to make use of a proprietary name) has been adapted with great success to popular requirements.

If we consider a cup of hot coffee, for instance, we know that if it is left standing for only a few minutes it will become cold, *i.e.*, it loses its heat. We must first understand how and where this heat goes before we can understand the action of the vacuum flask.

Heat is a form of energy, and as such is indestructible; it can pass from one substance to another of lower temperature, or it can be converted into mechanical, electrical or chemical energy, but it cannot vanish altogether. In the case of the cup of coffee there are four ways in which it can dispose of its heat : conduction, radiation, convection and evaporation. These will be referred to again later.

The illustration shows a section of a vacuum flask. It consists of a kind of double glass bottle, the inner one holding the hot coffee or other liquid, while the outer one forms a sealed space all round the inner bottle. The outside surface of the inner bottle and the inside of the outer one are silvered like a mirror by introducing a silver solution into the space. After the silver is deposited, the liquid is removed and the air pumped out of this space, leaving a vacuum, which is maintained by sealing up the glass-tube connection. The connection can always be seen as a kind of nipple near the base of the outer bottle.

Coming back to the cup of coffee, a certain amount of heat gets away by being passed on from molecule to molecule through the cup and anything in contact therewith. This flow of heat is called "conduction" and is prevented in the flask by removing the surrounding air, so that by surrounding the hot coffee with a vacuum there is nothing to conduct the heat away at all, except for a very little which leaks edgewise along the glass at the neck and through the cork.



Cross section through a vacuum flask

Anything that is hotter than its surroundings "radiates" heat. The sun, for example, radiates enormous quantities of heat in all directions, and our cup of coffee does the same thing on a lesser scale. Now if a vacuum could stop radiant heat we should get no warmth at all from the sun, for its heat has to traverse nearly 100,000,000 miles of space, which is a complete vacuum. Obviously, then, the vacuum space round the flask will offer no barrier at all to loss of heat by radiation. But radiant heat can be reflected in the same manner as light, therefore the silvered surface of the inner bottle reflects the radiated heat back into the bottle again. The reflecting properties of silver on glass are very nearly 100-per cent., so the clever device of silvering almost entirely prevents loss of heat by radiation. It is not used to make the article look pretty.

"Convection" has been mentioned as a cause of loss of heat. This means that as the heat is conducted to the surrounding air, the air becomes warm and rises, forming a current of air, which acts as a kind of vehicle to carry away the heat. These are termed convection currents, and in the case of the vacuum flask are effectively prevented by the simple means of putting a cork in the neck. There can, of course, be no convection currents at the walls of the bottle on account of the vacuum.

The fourth source of loss—evaporation—can be seen operating in the rising steam. A certain amount of the liquid becomes vaporised, and in the process of evaporation absorbs what is termed "latent heat." This is not quite so easy to explain as the other kinds of heat loss, but is very easily dealt with by the cork, which prevents evaporation and therefore stops heat loss from this cause. The action of a vacuum flask, the reader will know from his own experience, is very effective

A MODEL OF A CARGO VESSEL

By E. W. TWINING

This First Article on the Building of a Model Boat Deals with the Construction of the Engine. Next Month we Intend to give Constructional Details of the Boat

IN the issue of PRACTICAL MECHANICS for November last, I gave a description, illustrated by detail drawings, of a single-acting, single-cylinder, horizontal steam engine, the main purpose of which was that it might serve as an example of model-making suitable for beginners in the craft.

The simplicity of the principle on which that engine functions, particularly in regard to the piston and slide valve, is such that it commends itself for application to other forms of steam motors and other uses for the same; especially in such cases where the engine is only required to do useful work and is not called upon to follow the shape or outline of a prototype.

Such a case of usefulness is that in which a prime mover is wanted for driving the propeller of a model steamship; the engine being entirely out of sight and its exact form being of no consequence.

Less Accuracy in Fitting

It will be obvious to the accomplished model engineer, as well as to the tyro, that the making and fitting up of an engine which has no cylinder cover at the end nearest to the crankshaft, with a stuffing box through which a piston rod passes, no crosshead and slide bars, no slide valve in a closed steam-chest and no valve rod with its accompanying stuffing box and gland, must permit of very considerably less accuracy in fitting and alignment than does an engine in which all these things are present. Further, that in a double-acting cylinder, unless the workmanship is such that the highest degree of accuracy has been attained, there is a considerable loss of power due to friction in the piston and stuffing boxes. This is due to the want of alignment between the bore of the cylinder and the holes in the box and gland through which the piston rod passes. This fault may, too, be aggravated by the crosshead guides being out of line with the gland, with the cylinder bore or with both.

The great advantage accruing from the use of single acting cylinders—of the type which I originated for steam engine models when I was but fifteen years of age—lies in the fact that there is no piston rod, no crosshead, and no valve chest; moreover there are no long ports to drill from the valve face to the cylinder ends and through which ports the steam, on admission, has probably to be wiredrawn and most certainly has on the exhaust stroke.

In order to obtain the same horse power in the single acting principle as in the double acting, two cylinders have to be employed, each set in line, one with the other, on opposite sides of the crank. But the making of two such cylinders with their connecting rods, pistons and valves, involves, collectively, less work than does one only of the double-acting type, complete with slide-bars and crosshead. Beside the reduced labour called for in making, and the reduced amount of friction set up in working, there are several other advantages arising out of the use of the single acting principle and particularly out of the flat-plate type of slide valve. One of these is the better balancing of the moving parts; for ships the much lower centre of gravity of the mass of the engine and the simplicity of the lubrication, not only of the pistons but of the crank-shaft bearings and the connecting rod ends, all of which is automatic by splash from the crankcase, that is to say: where such crankcase is of the closed type. The valves receive some oil which is carried out of the cylinder by the exhaust steam.

Flat-plate Slide Valve

The advantage of the flat-plate slide valve is that the ports for steam and exhaust are cut straight through it, through the blocks of metal on either side of it and between which the valve slides. It follows therefore that neither live steam nor exhaust are compelled to pass through long and tortuous passages in entering and leaving the cylinder. In addition, there is the great advantage that boiler steam enters by a port separate from that through which the exhaust issues.

The only disadvantage lies in the facts that separate steam pipes have to be taken to each valve block and that the slide valve itself suffers some small amount of cooling at each end by exposure to the air.

Ship's Engine

The subject of the present article is, as I have indicated, a model ship's engine. It embodies the foregoing principle and possesses the added advantage that it can, if desired, be built up entirely of sheet metal, tubing, steel rod, etc., many bits and pieces of which can often be found in the average model-maker's scrap box. Actually no castings are necessary, and the time and cost of pattern-making is thus saved, though some people may prefer to have castings made for the crankcase.

I have prepared two drawings only, and these should be quite sufficient to enable any model engineer to take off all the needful particulars and build the engine. From these drawings it will be seen that a four-cylinder engine is intended, with cranks set at right angles. This, from the point of view of power developed, is equivalent to a two-cylinder, double-acting engine. The model can, of course, be built with two single acting cylinders only, set on opposite sides of the crankcase, but it must be remembered that it would not then be self-starting should the crank happen to be on a dead-centre.

Smaller Engine

It will be noticed that no figured measurements are given in the drawings. The reason for this is that some readers may desire a smaller engine or a larger one than others, according to the size of the vessel which is to be driven and the speed expected or required. So, I have, on the sectional views, appended scales, and by means of these all measurements can be taken off with a pair of dividers. I may point out that by the two scales two sizes of engine are indicated. The upper one, in Fig. 1, is to be used for cylinders having a bore and a stroke of 1 inch, which would be suitable for a model of a cargo vessel of about 6 to 7 feet in length. The other scale is for a ¾-inch by ¾-inch engine which would be capable of driving a ship having a length on water-line of about 5 feet.

For a given horse power in the engine and boiler the exact size of the vessel and its propeller depends very largely upon the speed at which the ship is to be driven through the water. A cargo steamer in model form is a very picturesque object, much more so, in my own opinion, than is a passenger liner, and a cargo boat moves at a comparatively low rate of knots.

Size and Speed

This matter of the size and speed of the model vessel is one upon which I do not pose as an expert, and as it is proposed that this article shall be followed by one from my friend and colleague, Mr. E. H. Clifton, who will write about and give drawings for a ship suitable for taking the engine, I will leave the matter to be dealt with by him. Then when the sizes and displacement of the hull are decided upon I will provide the reader with drawings for a boiler or steam generator, which will be arranged to fit into the

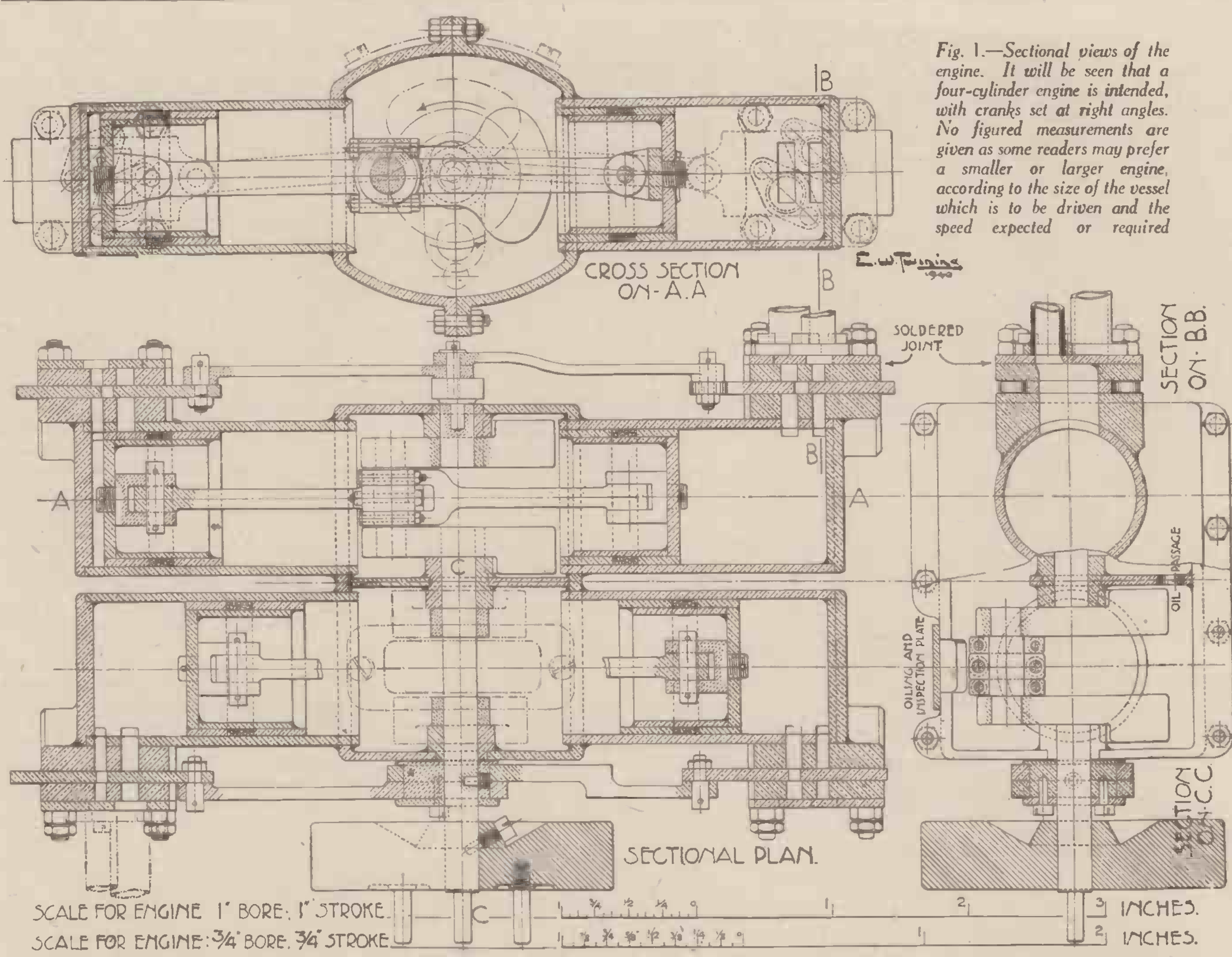


Fig. 1.—Sectional views of the engine. It will be seen that a four-cylinder engine is intended, with cranks set at right angles. No figured measurements are given as some readers may prefer a smaller or larger engine, according to the size of the vessel which is to be driven and the speed expected or required

space available for it within the hull.

Returning to our engine and the details of its construction, I have endeavoured to render a lengthy description superfluous by completeness and clarity in the drawings of which Fig. 1 are all sections and Fig. 2 external views. These latter call for no comment except to say that the upper drawing is an end elevation of the after end with flywheel omitted; the lower drawing is a plan and on the right hand an elevation of the starboard side. This last shows a suggested way of distributing steam to the four slide valves and of collecting the exhaust. The main steam pipe from the boiler is brought to a point over the centre of the engine; there it enters and is soldered into a tubular box out of which four branch pipes issue radially. These branches terminate in the flanges screwed to the valve cover-plates shown in the drawings. The exhaust pipes had better, perhaps, be separate for each pair of cylinders, one pipe on each side. These can be brought together and enter the base of the funnel, or smokebox, side by side. But really this matter of pipework will be best dealt with later and after the ship and the boiler have been designed.

The Flywheel

As I have already indicated all the parts of this engine can be built up—with the exception, of course, of the flywheel. Although some readers may prefer a cast crankcase I recommend the built-up method, for eventually it will be found to involve the lesser amount of work. A casting or pair of castings could not be made from a simple pattern, and actually a somewhat intricate corebox would be needed in addition to a pattern, in order to form the hollow interior of the crankcase.

It will be seen that the case is in two halves, as are also each of the three bearings for the crankshaft. To make each half, by building up, six pieces of sheet brass will be required : two ends, a middle partition, the wrapper plate and two flanges. The wrapper, which is the main plate which receives the cylinders, is first measured up and bent as shown in the cross section; then the end bearing plates and the middle partition are cut out to fit the wrapper and are silver-soldered in place. The edges of all the assembled plates may then be faced, laid upon a flat piece of firebrick and the flanges similarly silver-soldered. Each of the two halves of the crankcase should then be fine-faced by rubbing on a sheet of emery cloth laid upon a surface plate and finally, ground together and drilled ready for bolting.

The Case

The assembled case may next be laid upon the surface plate—for which a piece of plate glass serves excellently as a substitute—and carefully marked out, with square and scriber, for the cylinder centres and for the centre-line of the crankshaft. The two halves are then separated, circles scribed and cut out to take the cylinders and the markings for the shaft centres scribed across the middle partition on each half of the case. It is, of course, most important that all three of these bearings shall be exactly in line.

The crankcase is now bolted together again and the end holes drilled and opened out to receive the spigots on the bearings; see plan and the section C.C. The centre partition cannot very well be drilled with accuracy and, therefore, from the scribed centre it will be necessary to mark off with dividers above and below the line and then to file the metal away with a half-round file until the turned bearing fits. All three of the actual bearings are split and, since it will not be possible to saw these into halves after turning, it will be necessary to saw first and turn afterwards. Take a piece of round rod of sufficiently large diameter, divide this with the hacksaw lengthwise, on its centre-line, file the sawn faces flat and soft solder them together again. Now drill down lengthwise, following the soldered joint, to a diameter to fit the shaft. Turn the outside to the form shown in the drawings, including the shouldering down to fit the openings in the crank-case plates, part off in the lathe for each of the three bearings and separate the halves by unsoldering. These half bearings are then silver-soldered into their respective places in the crankcase.

The Cylinders

The cylinders are made from brass tubing, carefully selected for smoothness and circular truth. Cylinder covers are turned from thick brass plate, shouldered and soldered in.

The valve-face blocks may be small castings, but I think this had better be decided by each maker of the engine for himself. Some people would not hesitate to take a piece of brass bar, long enough for all four blocks, mount it either on an angle-plate carried on the lathe faceplate or else on the saddle of the lathe, and with a boring tool in the one case or a boring bar in the other, would machine the hollow, which is to saddle on to the cylinders, at one operation, sawing off each block afterwards. It *is* possible to build this engine without a lathe, and if none is available I suggest that the least laborious way of providing these blocks is to make a small wooden pattern, get a gunmetal or brass casting and finish all off with half-round and other files.

There is one other part—or rather four of them—which also may be cast if preferred, namely the webs and counterbalances of the cranks. Obviously these are best made from mild steel and are machined from pieces of plate; but it would be quite practicable—and I think they would be reliable—to make them of hand-cast gunmetal. In either case the webs, shaft and crank-pins are to be silver-soldered together.

As will be seen the pistons are built up, the piston trunks being tubes of two diameters, one outside of the other. This method of using two tubes enables us to leave a gap in the outer one to receive the soft cotton packing. The pistons should, when made, be a tight fit in the cylinder, and should then be lapped in, using first the finest flour emery followed by metal polish. They should, after lapping, make a perfect sliding fit, and with a film of oil between piston and cylinder, and the ports covered, bear compression of air for a long period without leakage.

Slide Valves

The slide valves are simple pieces of flat brass plate as are also the cover plates; these latter are double, i.e., each made up of two pieces, soldered together. The one next to the valve has steam and exhaust-port openings cut in them exactly opposite those in the cylinder and block, whilst the outer one has circular holes corresponding with the apertures of the steam and exhaust pipes.

Both sides of the valve and both the faces between which the valve works have to be ground true, preferably on plate glass, with abrasive gradually reducing in fineness to that of metal polish. Finally the pairs of surfaces which have to work together should be ground together with the polish.

A Disc Crank

For driving the forward valves a small disc crank is adopted, with two rods somewhat like small connecting rods, but on the after end the valves must be driven by an eccentric, for a reason which will be obvious. Here one sheave only need be fitted on the shaft, and this can take both eccentric rods. The straps, or eyes of the rods, need not be split in the usual way; it will be more simple to fit a removable cheek on the sheave which will allow the rods to be passed into place.

The flywheel is of cast iron and is secured by one set-screw. In the after side of the wheel there are two pins which will engage with a driven plate on the end of the propeller shaft. Alignment of the engine with the propeller shaft is secured by a third pin projecting from the centre of the crank shaft; this fits into a hole in the centre of the driven plate.

It will, perhaps, be noticed that in the drawings I have shown no brackets or other means of mounting and holding the engine. For steamship work I think it best to defer dealing with this until the hull is designed.

(*To be continued*)

Sindbad Up-to-date

THE Advisory Committee on inventions at the Ministry of Supply are the recipients of a multiplicity of suggestions. Doubtless many of these are unworkable, although dear to the hearts of the proposers. The average inventor makes a pet of his idea, regarding it with the favourable bias which the mother invariably feels towards her firstborn. But while cold impartiality finds it necessary to reject a number of ideas, care is naturally exercised lest in sifting the wheat from the tares really golden ears may be rejected.

Some visionary in the United States has suggested an electro-magnet which would draw to the side of a battleship a submarine and electrocute the crew of the latter.

This impracticable notion recalls one of the tales of that remarkable traveller, Sindbad the Sailor. He told how once his ship was, by some mysterious power, irresistibly attracted towards a mountain on the coast. When the vessel approached the shore, the ship suddenly went to pieces. All the nails in its planks were forced out and flew to the slopes of the mountain, which was a huge loadstone!

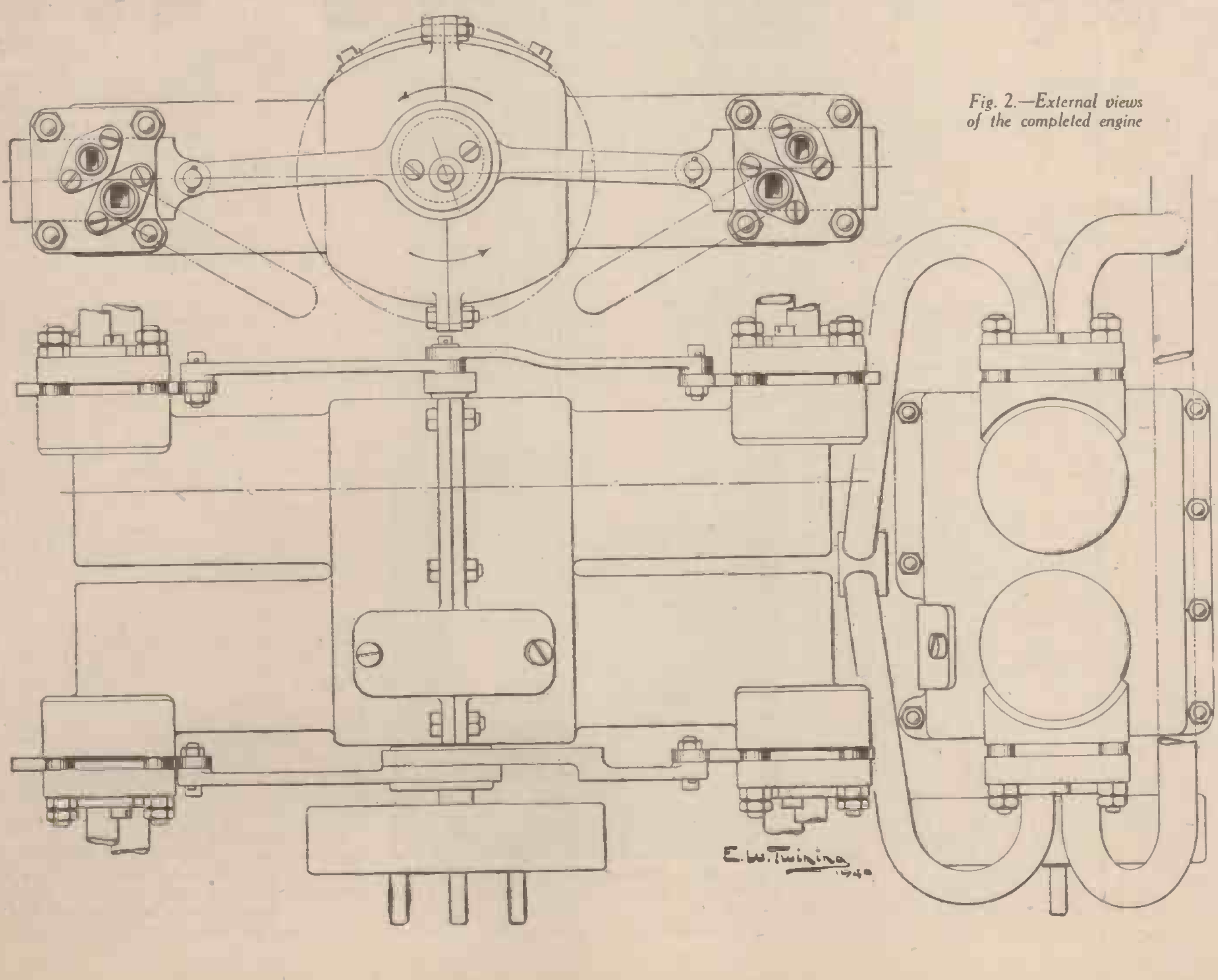


Fig. 2.—External views of the completed engine

Chemistry for Beginners

No. 12.—The Luminous Element—Interesting Experiments and Facts Concerning Phosphorus

Preparing hydrogen phosphide or "phosphine" by boiling yellow phosphorus with caustic soda solution in a flask. The bottle on the left contains marble chippings and dilute hydrochloric acid in order to generate carbon dioxide gas which is led into the flask to displace the air therein before beginning the preparation of the hydrogen phosphide

THE element phosphorus bears a strange history. Despite the fact that it is present in our brains and in those of most animals, as well as existing abundantly—in the form of calcium phosphate, $Ca_3(PO_4)_2$,—in all animal and human bones, the element itself was not really scientifically examined until the great chemist, Scheele, in 1771, obtained it by heating burnt and powdered bones with sulphuric acid.

Previous to this, phosphorus, although known, had been a rare curiosity. It seems to have been first discovered by a German alchemist named Brand in either 1668 or 1669. Brand, like all other alchemists, diligently sought for the secret of the "Philosopher's Stone" which mythical commodity was considered to possess the power of turning silver and other metals into gold. Curious, indeed, were the many highly absurd methods which some of the alchemists adopted in their search for the Philosopher's Stone. Brand, the alchemist of Hamburg, sought to make the Philosopher's Stone, or, at least, an extract of it, by concentrating urine and then by distilling it with sand. Needless to say, he failed in his quest, but, at least, this experimenter did stumble across one curious discovery, for in the receiver of his alchemical retort he found a few flakes of a strange and altogether unknown material which actually shone in the dark with a pale, mysterious light and which took fire violently almost at the very touch.

A Close Secret

Brand made quite a lot of money out of his phosphorus, the mode of preparation of which he guarded as a close secret. Then he sold his secret to a few others, with the result that the newly-discovered material began to be exhibited at Royal courts for the amusement and delectation of European princes and monarchs.

Robert Boyle, the "first of the English chemists," managed to prepare a small quantity of phosphorus in or about the year 1680, although whether he obtained the secret from the Continent or effected an original discovery we have no certain means of knowing. It was, however, as we have already seen, not until the time of Karl Scheele, the Scandanavian chemist, just about a century after Brand's first discovery of phosphorus, that this peculiar substance was brought into the open, as it were, and stripped of all the masses of mystery and fantasy with which it had formerly been clothed.

Preparing phosphorus pentoxide by burning phosphorus in air under a large bell jar. The white clouds of the pentoxide collects as a deposit on the inner side of the jar

Phosphorus is a peculiar element. It is made nowadays from bone ash, by heating this material with sand and coke in an electric furnace, whereby a complex chemical reaction takes place resulting in the liberation of free phosphorus which distils over into a suitably-designed receiver. It is, from a practical standpoint, impossible to imitate the manufacture of phosphorus on the small scale, and, therefore, time should not be wasted in the home laboratory in vain attempts at the preparation of this element.

Yellow and Red

The element exists in several different forms, the two commonest of which are "yellow" and "red" phosphorus.

Yellow phosphorus comes to the market in the form of cream coloured, waxy-looking sticks, which, when exposed to air in the dark, emit a pale greenish light. The material smells unpleasantly of garlic, and, what is more, it ignites and burns violently upon the slightest friction. For this reason yellow phosphorus is *always* kept, cut and in other ways manipulated completely under water. It must never be handled with dry fingers, otherwise a really bad phosphorus burn may result from the element taking fire in consequence of the heat and friction of the fingers.

The glow of yellow phosphorus is very characteristic of the element. It is, in fact, an example of "cold fire," for the luminescence of the material is, in reality, due to the slow oxidation or combustion of the phosphorus. Yet, curiously enough, if a piece of yellow phosphorus is placed into an atmosphere of pure oxygen, its characteristic luminescence diminishes to a very great extent. Again, the glow of phosphorus is stopped if the air be even slightly compressed or if it contains traces of essential oils such as turpentine and, also, various gases. Even at the present day, we do not know everything about the glow of yellow phosphorus, that strange phenomenon which has excited man's attention for more than two and a half centuries, but we do know one thing about it, and that is that the effect is in some way due to the gradual and almost imperceptible oxidation of the yellow phosphorus.

Red Phosphorus

The second well-known form of this curious element is dark brick red in colour. Hence, it is known as "red phosphorus." Now red phosphorus neither glows in the dark, nor does it readily ignite upon friction. Yellow phosphorus is very poisonous, but you may eat a spoonful of the red variety of this element without doing yourself any more harm than upsetting your digestion. But, from a chemical standpoint, red phosphorus is identical in properties with yellow phosphorus. It enters into exactly the same reactions, although it does not undergo them so violently as does its yellow relation. Hence, for synthetical work and for most chemical preparations, the red variety of phosphorus is the one which is the most employed in the laboratory.

On the industrial scale, red phosphorus is made simply by heating yellow phosphorus (in the absence of air) to a temperature of about 260°C. At this temperature, an inter-molecular change takes place in the yellow phosphorus, resulting in its conversion into the more harmless and less violently reactive "red" variety.

We can see for ourselves this curious change taking place in the laboratory.

Take a few small grains of yellow phosphorus, carefully dry them with blotting-paper and introduce them into a short length of glass tubing, sealed at one end. Now very carefully heat the other end of the tubing (keeping the lower end of the tubing immersed in cold water in order not to allow the contained yellow phosphorus to heat up and so to ignite) and seal it up as quickly as possible.

Now suspend the phosphorus tube in the neck of a flask containing within it some high-boiling-point liquid such as dibutyl phthalate, or even medium-thick oil. When the flask is heated, the hot vapours from the liquid will heat up the yellow phosphorus in the tube, raising it to the temperature of its conversion into red phosphorus, which conversion will take place quickly and visibly. If a small trace of iodine is placed into the phosphorus tube before sealing it off, this change will take place even more readily and at a considerably lower temperature.

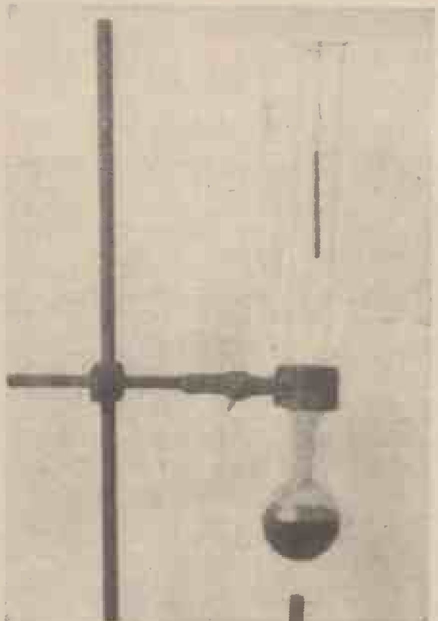
The above experiment illustrates the principle of red phosphorus manufacture, an industrial process which is nowadays undertaken on a very large scale in view of the constant and ever-increasing demands for red phosphorus for the manufacture of matches, fireworks, smoke bombs and so forth.

Phosphoric Oxide

When either red or yellow phosphorus is ignited, it burns with a ghostly yellow light and with the emission of vast clouds of dense white "smoke," which "smoke" consists mainly of phosphoric oxide, P_2O_5. This phosphoric oxide (or phosphorus pentoxide, as it is sometimes termed) is a most peculiar white, voluminous powder. It is readily obtained by allowing a quantity of red or yellow phosphorus to burn under a large glass bell jar or other enclosure and then by rapidly scraping the deposit of the oxide off the sides of the jar. The chief characteristic of this phosphoric oxide is its exceptional affinity for water. It very rapidly abstracts moisture from the air, becoming wet and pasty in the process, and for this reason it is frequently employed in chemical operations for the effective abstraction of the last traces of moisture from gases. Also, when phosphoric oxide is dissolved in water and the liquid boiled, ortho-phosphoric acid, H_3PO_4, is formed.

There are several other oxides of phosphorus. One, phosphorus oxide, P_2O_3, is formed by burning phosphorus in a regulated supply of air, whilst another oxide—phosphorus tetroxide, P_2O_4—is created by heating phosphorus oxide in a sealed tube to a temperature of 440°C. These oxides, however, do not interest the beginner in chemistry, and for further details of their characters and preparation a fairly advanced textbook of chemistry must be consulted.

Besides forming several oxides, phosphorus is capable of giving rise to at least two *hydrides*, or compounds of the element with hydrogen. One of these hydrides is an evil-smelling gas, the other comprising a liquid which is actually spontaneously inflammable, that is to say, one which will take fire immediately on contact with air.



By this simple apparatus, the change of yellow into red phosphorus can be observed. A small quantity of yellow phosphorus is sealed in a piece of glass tubing which is then suspended in a vapour of a high boiling-point liquid oil

Hydrogen Phosphide

The best way to make phosphorus hydride (or hydrogen phosphide, as it is better called) is by dropping pieces of calcium phosphide into water. This experiment must be done out of doors, owing to the bad odour of the evolved hydrogen phosphide or "phosphine." The gas, also, is poisonous, but no harm can come of experiments with it, provided that they are performed out of doors.

When lumps of calcium phosphide are dropped into water, the hydrogen phosphide which is generated is spontaneously inflammable, and the bubbles of it which break through the surface of the water instantly take fire on meeting with the air. This is due to the fact that when water acts upon calcium phosphide, *two* hydrogen phosphides are generated—one, the ordinary phosphine, PH_3, which is not spontaneously inflammable, and the other, the hydrogen phosphide, P_2H_4, which *is* spontaneously inflammable. Hence it is that by the agency of the latter hydrogen phosphide, the issuing gas, as a whole, is ignited.

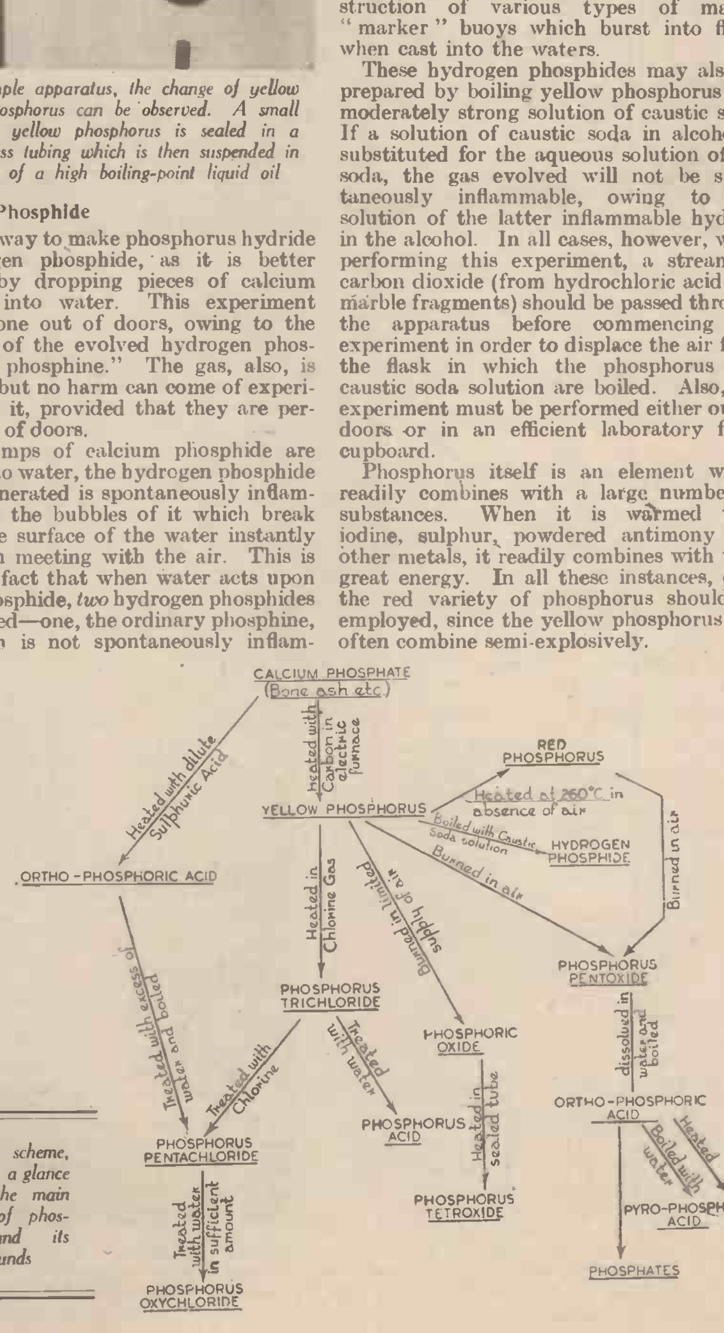
Incidentally, this spontaneously inflammable hydrogen phosphide is really a liquid. It can be obtained by passing the gaseous products of the interaction between water and calcium phosphide through a U-tube surrounded by ice or a freezing mixture, whereby the liquid (and spontaneously inflammable) hydrogen phosphide condenses and the non-spontaneously inflammable gas passes on. Needless to say, before any experiment of this nature is tried, all the air must be swept out of the apparatus by means of a current of carbon dioxide gas, and the condensed liquid (spontaneously inflammable) hydrogen phosphide *must not* be brought indoors.

Marine "Marker" Buoys

The production of this spontaneously-inflammable hydrogen phosphide has a most important application in the construction of various types of marine "marker" buoys which burst into flame when cast into the waters.

These hydrogen phosphides may also be prepared by boiling yellow phosphorus in a moderately strong solution of caustic soda. If a solution of caustic soda in alcohol is substituted for the aqueous solution of the soda, the gas evolved will not be spontaneously inflammable, owing to the solution of the latter inflammable hydride in the alcohol. In all cases, however, when performing this experiment, a stream of carbon dioxide (from hydrochloric acid and marble fragments) should be passed through the apparatus before commencing the experiment in order to displace the air from the flask in which the phosphorus and caustic soda solution are boiled. Also, the experiment must be performed either out of doors or in an efficient laboratory fume cupboard.

Phosphorus itself is an element which readily combines with a large number of substances. When it is warmed with iodine, sulphur, powdered antimony and other metals, it readily combines with very great energy. In all these instances, only the red variety of phosphorus should be employed, since the yellow phosphorus will often combine semi-explosively.



Student's scheme, outlining at a glance some of the main reactions of phosphorus and its compounds

With chlorine, phosphorus forms two well-known compounds: phosphorus trichloride, PCl_3, which is a colourless, mobile, fuming liquid, boiling at 76°C.; and phosphorus pentachloride, PCl_5, which is a white solid, having an irritating and pungent odour.

These two compounds are readily made. To prepare the trichloride, merely pass *dry* chlorine gas over red phosphorus which is very gently warmed in a bulb tube or in a small retort. The liquid phosphorus trioxide, PCl_3, will condense in the well-cooled receiver, and it can be purified and freed from any contaminating phosphorus pentachloride by simple distillation.

Phosphorus Pentachloride

Phosphorus pentachloride, PCl_5, is prepared by allowing *dry* chlorine gas to flow on to the surface of a quantity of phosphorus trichloride contained in a well-cooled flask. The chlorine is rapidly absorbed by the phosphorus trichloride, which is in consequence converted into the solid phosphorus pentachloride.

Both phosphorus trichloride and phosphorus pentachloride are unstable in the presence of water. Phosphorus trichloride is decomposed by water into hydrochloric and phosphorus acids:

$$\underset{\text{phosphorus trichloride}}{PCl_3} + \underset{\text{water}}{3H_2O} = \underset{\text{phosphorus acid}}{H_3PO_3} + \underset{\text{hydrochloric acid}}{3HCl}$$

whilst phosphorus pentachloride is decomposed by water into hydrochloric acid and phosphorus oxychloride, a liquid boiling at 107°C.:

$$\underset{\text{phosphorus pentachloride}}{PCl_5} + \underset{\text{water}}{H_2O} = \underset{\text{phosphorus oxychloride}}{POCl_3} + \underset{\text{hydrochloric acid}}{2HCl}$$

Hence it is that only perfectly dry chlorine gas must be used in the preparation of the above two chlorides of phosphorus.

The best way of making phosphorus oxychloride, $POCl_3$, is to add water to phosphorus pentachloride very carefully, and drop by drop until the white solid turns to a liquid.

Of the various important acids containing phosphorus little of practical importance can be set down here. The most important of these acids is ortho-phosphoric acid, H_3PO_4, which, as we have already noted, may be prepared by dissolving phosphorus pentoxide in water and by boiling the liquid. Thus:

$$\underset{\text{phosphorus pentoxide}}{P_2O_5} + \underset{\text{water}}{3H_2O} = \underset{\text{ortho-phosphoric acid}}{2\,H_3PO_4}$$

This acid, when concentrated, forms a thick syrup. It gives rise to all the various *phosphates*, and it is manufactured on the large scale by the action of sulphuric acid on powdered, calcined bones. By this action, insoluble calcium sulphate is produced from the calcium phosphate in the bones and, also, at the same time, ortho-phosphoric acid is liberated. The calcium sulphate, being a white insoluble powder, is filtered off, leaving the ortho-phosphoric acid to be concentrated.

Pyro-Phosphoric Acid

When ortho-phosphoric acid is heated to about 215°C., it parts with water and becomes converted into pyro-phosphoric acid:

$$\underset{\text{ortho-phosphoric acid}}{2H_3PO_4} - \underset{\text{water}}{H_2O} = \underset{\text{pyro-phosphoric acid}}{H_4P_2O_7}$$

This pyro-phosphoric acid is a white crystalline solid, which, when boiled with water, changes back again into ortho-phosphoric acid.

As we have already signified, this ortho-phosphoric acid is the parent acid of the various phosphates which are found in rocks and in animals. Human bones, for instance, contain about 62 per cent. of pure calcium phosphate, and to this material they owe entirely their strength and their rigidity. Many rocks contain calcium, magnesium and aluminium phosphates, whilst these phosphates, also, are found in all fertile soils, their presence being essential to the growth and well-being of crops and plants.

Phosphorus, indeed, in its various combinations is one of Life's vital elements. Animals and plants (and often micro-organisms, too) must have adequate supplies of phosphorus compounds for their successful existence. Cut off the phosphorus supply of any one of these living beings and the creature immediately begins to wilt and eventually it dies.

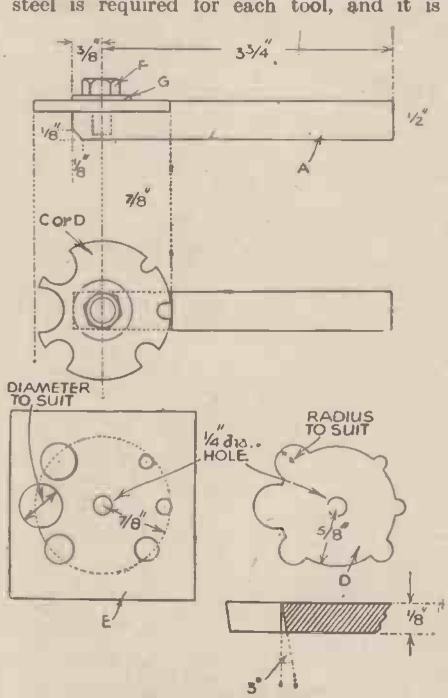
The role of phosphorus in nature is an exceedingly large and an overwhelming one. Its study is different, perhaps, to the study of phosphorus in the laboratory. Yet in all its reactions, the element phosphorus shows a characteristic great activity, as the student of chemistry, after performing experiments with this strange elemental material, will quickly come to realise.

Forming Tool for Turning Radii

A Useful Device for the Workshop

WHEN carrying out machining operations for models, etc., it is sometimes found that a number of radii have to be turned on each fitting.

To make, and change in the tool post, a form tool for each radii is a lengthy and expensive job, as a piece of high-speed tool steel is required for each tool, and it is necessary to forge to shape and finally grind a piece of steel ½ in. thick. In order to obviate this tedious job the tool shown in the illustration was designed.



Details for making the tool

The shank A is a piece of ½-in. by ½-in. mild steel shaped as shown, drilled and tapped to take the ¼ in. dia. Whitworth stud B. The concave form blade C is made from a piece of ⅛ in. thick high-speed steel shown at E.

Drilling Operations

The ¼ in. dia. attachment hole in the centre is first drilled, and on the pitch circle indicated, a number of holes are drilled equal in diameter to twice the radii required.

This piece is then cut to shape round the dotted line as shown, and the clearance filed as indicated at H, and finally hardened and tempered in accordance with the steel manufacturer's instructions.

The Convex Form Blade

The convex form blade is made from a similar piece of ⅛ in. thick steel, drilled for the attachment hole, marked out and carefully filed to the required form, hardened and tempered as for the previous blade. It is advisable to clearly mark the dimension of each radii, and by doing this avoid mistakes and spoilt work.

Using the Tool

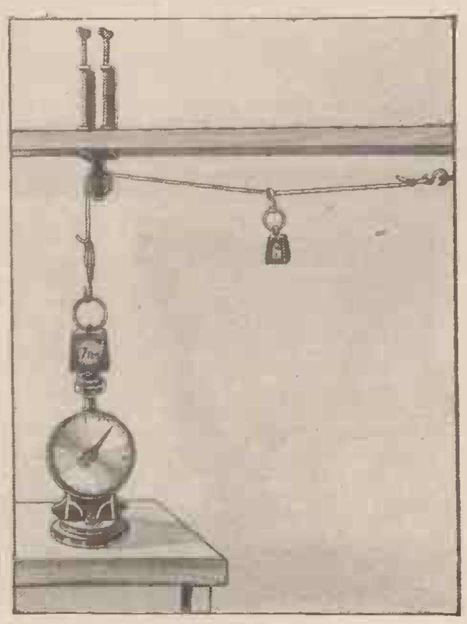
In operation the form blade is fitted to the shank and clamped in position by means of the washer G and nut F.

With this tool in the tool post a rapid change may be made from one radii to another, and when a collection of suitable blades has been made, you will have the assurance of having the right tool to tackle the job.

A CURIOUS EXPERIMENT IN MECHANICS

THE illustration shows a spring balance partly supporting a weight of 7 lb. with a 1-lb. weight hung on the centre of the supporting cord—but the spring balance registers *under* 3 *lb*. What has become of the extra 4 lb.?

Reply Next Month



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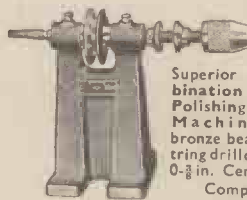

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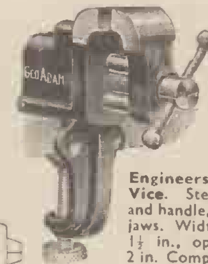

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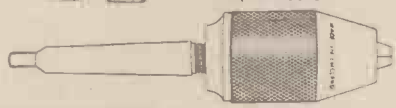

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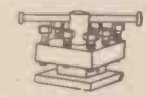

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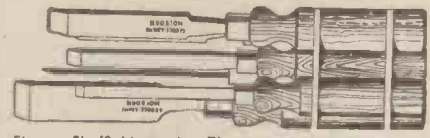

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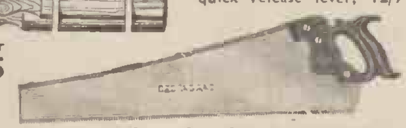

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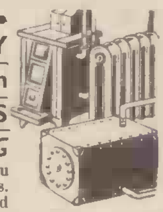

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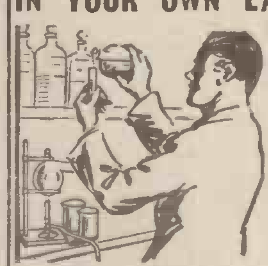

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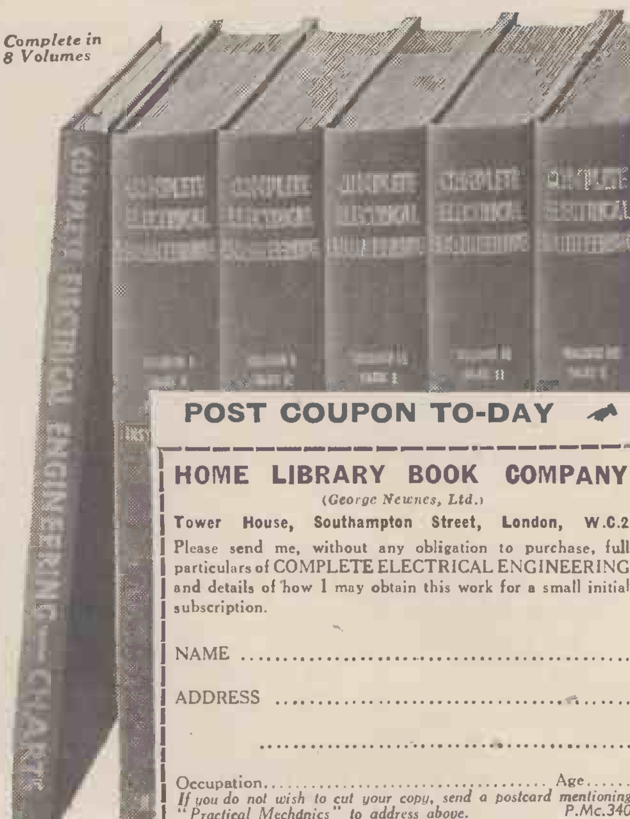

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Thermometer for Tobacco Pipes

TO prevent the pipe smoker from smoking his pipe is the object of a new invention. That sentence does not imply the prohibition of the tobacco pipe; it means that some men smoke their pipes in addition to the tobacco contained therein. They puff so rapidly and continuously that the tobacco glows like a fiery furnace. The sequel is a far from cool smoke and damage to the pipe.

The invention in question comprises a tiny heat-indicating dial attached to the side of the bowl and visible to the smoker. This enables him to protect the bowl from being partially consumed. It also furnishes him with means for determining the amount of heat in various brands of tobacco. The inventor states that he is not necessarily concerned with the actual degree of heat generated from tobacco, as expressed in technical heat units; he is desirous of showing a comparative reading, as, for instance, the degree point beyond which a pipe may be injured. The Lilliputian thermometer will warn the smoker when his pipe has a temperature.

Bus Seat Indicator

A CLERICAL gentleman of my acquaintance once remarked that his young son had not yet decided whether he would be a parson like his father or a tram conductor. The two vocations are not as dissimilar as appears at first sight. Both churches and trams have an aisle with an official making a collection, and each of these callings has its difficulties. The clergyman too often has to lament the number of empty pews in his church, while, in the case of the conductor, his trouble is that at times he cannot accommodate all the eager folks who require seats.

As the regulations regarding overcrowding are stringent, conductors of trams and buses will be interested in a new enumerator and indicator of the number of seats available on the upper decks of passenger vehicles. The counting and indicating mechanism is operated from two passenger-depressible spring-returned stair-treads. Numbered dials are visible to the inspector, the conductor and the public. They may show one face towards the interior and another towards the exterior of the bus. Passengers, therefore, will be able to see at a glance when there is standing room only.

Artificial Ankle

SINCE the days of Long John Silver with his timber leg, there has been considerable development in the construction of artificial limbs. Incidentally, it may be mentioned that the cost of these imitations of man's nether limbs has substantially increased. But, although compared with the crude peg worn by the pirate of "Treasure Island," the artificial limb to-day is costly, it is far more natural and effective.

I note that in the United States there has been granted a patent for an improved artificial ankle-joint fitted with bearings and a rubber cushion to prevent shock.

The skill of the modern mechanician can produce artificial limbs approximating very closely to those with which Nature has endowed the human race. But they do not always deceive the animal world. For example, a friend of mine who, owing to the last war, literally has one leg in the grave, finds that his imitation leg is avoided by the family cat. The latter prefers to sit upon a natural limb which imparts warmth and into which, after the feline manner, the animal can stick his claws.

Genial Warmth for Towel Rails

JACK FROST has, during the opening weeks of 1940, converted our country into a huge refrigerator. His bitter onslaught is not an unmixed evil; it decimates a countless army of hostile germs. And it elicits a *Te Deum* from the plumber and coal merchant. Nevertheless, antidotes to the arctic conditions are very welcome to the shivering public. One of these is an effective heated towel rail in the bathroom. Self-contained towel rails have been on the market for many years. But they have contained water, which must be periodically replenished, owing to the loss caused by evaporation. The use of oil as the heat circulating means in radiators and ovens has also been suggested. However, with such a method it appears that temperatures are attained which would burn the hand which came too near.

In this connection the chief object of a new invention is to supply a towel rail containing a medium which will not exceed a desired maximum temperature. The device consists of a towel rail having a sealed liquid circulating system and a modified source of heat. The liquid is a mineral oil with a viscosity which will never reach a temperature that will burn the hand which happens to touch the rail.

This invention should add to the amenities of the bathroom by ensuring a dry towel of genial warmth.

The information on this page is specially supplied to "Practical Mechanics" by Messrs. Hughes & Young (Est. 1829), Patent Agents of 9 Warwick Court, High Holborn, London, W.C.1, who will be pleased to send readers mentioning this paper, free of charge, a copy of their handbook, "How to Patent an Invention."

Baby and Puppy Safe

ONE of the latest things in air raid precautions is a gas-proof cabinet, which can be used for a variety of purposes. Into it one may safely insert the baby or Fido, the faithful occupant of the hearthrug. It may also be employed for the storage of food or any article which it is desired to protect from poisonous gas. I presume this collection of living creatures and inanimate objects would not be placed together in the cabinet.

The structure may be composed of wood or any suitable sheet material. It has the air-inlets located at the lower part and the outlets at the upper part of the cabinet. The aim of this arrangement is to enable the fresh air to flow upwards.

Bombs for Boys

THE fashion of children's playthings tallies with the times. I note that the United States Patent Office has granted a patent for a toy bomb. Some educators will lament the existence of such a horrific toy. But it is a fact that youngsters—principally boys—have always delighted to play at soldiers.

Another toy which has been protected in America is not of a military type. It is apparently an elaborate relation of the game known as Tiddley-winks, which, it will be remembered, aims at projecting counters into a bowl. The new game has triple bowls elevated one above the other.

I conclude that the player who succeeds in lodging his counter in the highest bowl adds materially to his score. This form of amusement might counter the gloom of the black-out.

Whetstone Holder

THE scythe and the sickle play an important part in the reaping of the harvest. Like a razor, they must be sharpened at regular intervals. To attain the necessary keen edge, the reaper usually carries a small whetstone and the rythmic rubbing of the blade is a familiar sound in the harvest field. Now, a sharpening stone sometimes becomes fractured and it is not advisable for the farm labourer to continue using the broken portion, because, owing to its shortness, he would have to hold it dangerously near to the cutting edge of the tool. To throw it away would be a reprehensible act in this time of super-economy.

In order to provide for this emergency, an inventor has devised a holder and a handle for a broken sharpening stone which comprises a socket capable of contraction by a nut and bolt to grip the stone. The principle of the arrangement is that of a holder designed to use up pencil stumps.

By the way, one wonders how Old Father Time keeps his scythe in good condition.

Ornamental Steel Helmet

THE steel helmet, so familiar an official headgear in our country to-day, is not a thing of beauty. And valuable though it be as a shield, it certainly does not add dignity to the wearer. The Tin Hat, as it is colloquially styled on our side of the Atlantic, is known as a Safety Hat in America.

An ornamental design for this helmet has recently been registered in the United States. While not reducing the efficiency of the head cover as a guard, an agreeable pattern would relieve the plainness. And a corrugated design might add to the helmet's power of resistance.

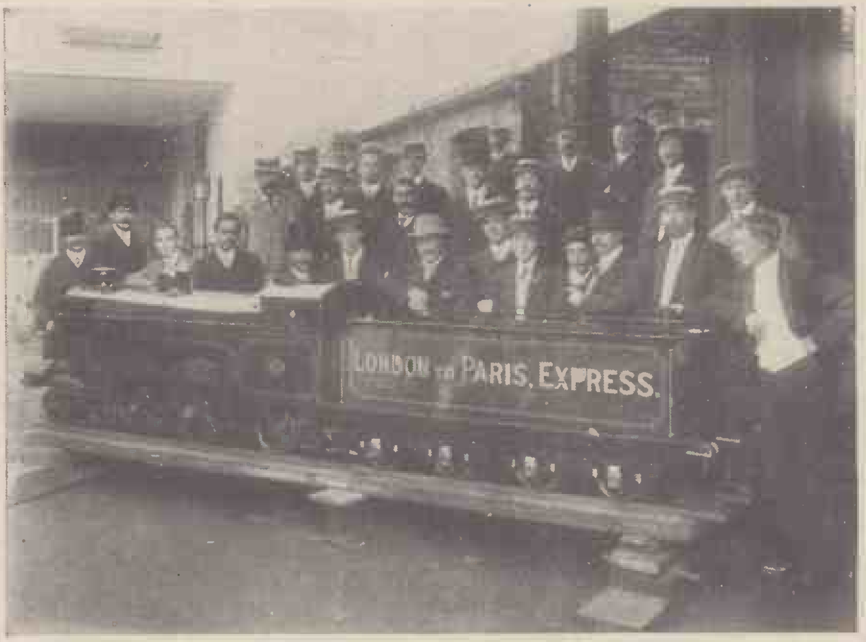
Comfort for the Couch

"NEVER mind the warming pan" was part of the documentary evidence given in that *cause célèbre*, Bardell *v.* Pickwick. In these chilly days, or rather nights, the warming pan no longer performs its kindly office of driving the cold from our sheets. To-day, in all its copper glory, looking like a banjo, it hangs on the wall in some houses; its sole purpose in life now is that of an ornament.

One of the most up-to-date methods of heating, warming and airing beds is an apparatus for which an application for a patent has been accepted by the British Patent Office. This appliance includes a heating element mounted in a cage-like frame. The heat is carried within a tube having, at its extremities, a series of radial arms. The appliance is placed in the bed with the clothes held out of direct contact with the heater. This device will add materially to the cosiness of the couch.

"MOTILUS" PEEPS INTO THE

"Motilus" Looks Back Over Old



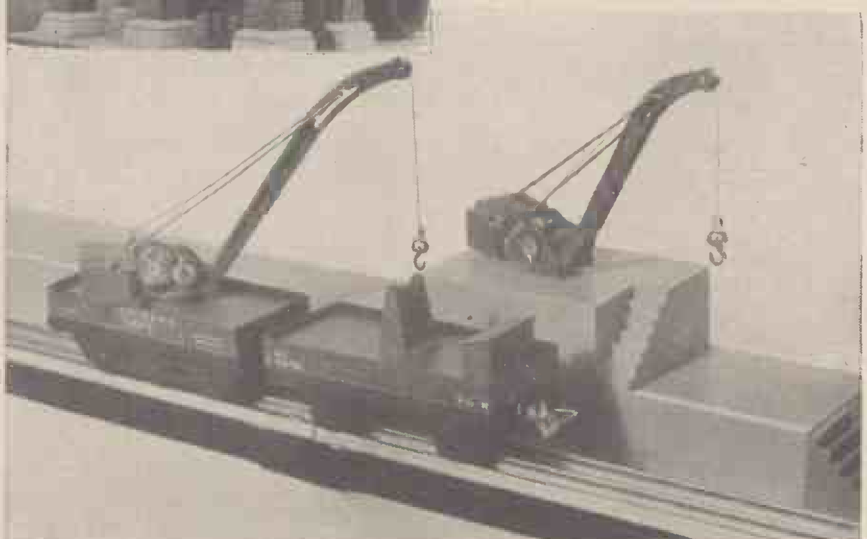
A thirty-year-old picture of a 15-in. gauge Atlantic-type locomotive. On the extreme right is Mr. W. J. Bassett-Lowke

A 15-in. Gauge Engine

GLANCING through some old photographs the other day, I came across what I consider quite an interesting picture, taken about thirty years ago in the yard of a famous and old-established firm which is still, despite these trying times, in the land of the living. The central feature is a 15-in. gauge Atlantic-type locomotive, made for the miniature railway at the Franco-British exhibition at Wembley in 1908. It was used for carrying visitors around the grounds of the exhibition and belonged to one of those pioneer model railways, which have been reproduced at practically every international exhibition held since (with the possible exception of the Zurich exhibition, where I remember a waterway with boats taking its place). Fifteen-inch gauge is extremely powerful in the model world, the real railway itself is only four times bigger, but let us return to the photograph—there are several well-known personalities of the model world in the group. On the top row, centre back, wearing cap, is Mr. J. T. Lowke, father of Mr. W. J. Bassett-Lowke, looking very youthful on the extreme right front. Above "W.J." and slightly to the left without hat is Mr. H. F. R. Franklin, a pioneer director of Bassett-Lowke, Ltd. The youthful looking person just behind Mr. W. J. Bassett-Lowke is Mr. W. H. Rowe, who now has to his record a third of a century in loyal service on the staff of this model-making company. Perhaps most important of all is the man on the left of Mr. J. T. Lowke—Mr. Fred Green, one of the first builders in this country of large-scale steam model locomotives—and the builder of this model.

Unique Beam Engine

A short time ago I paid a visit to Loughborough College in Leicestershire and was interested to see in the grounds an old beam engine—the work of James Watt. On inquiry I discovered that this unique piece of machinery had been presented to the Governors of the College by the Metropolitan Water Board in 1932. It struck me at the time how little seems to be known of the engines of Watt in these days. Perhaps I have talked with the wrong persons, but I meet people who have little idea of the Watt Parallel Motion, the Jet Condenser, the Plug Tree, or Snifting Valves. The average person will tell you that Watt invented the steam engine and Stephenson the locomotive, though actually this is far from the truth. What each did was to effect outstanding improvements, so that the two types of engines became "a practical proposition."



(Centre).—This old beam engine is the work of James Watt and stands in the grounds of Loughborough College, Leicestershire. (Below).—A model of a breakdown crane truck outfit, one of the latest developments in "00" gauge railways

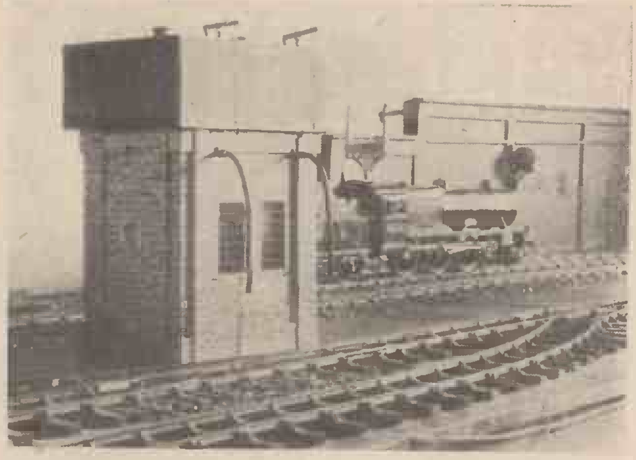
As long ago as 1829 much preliminary work had been done with the problem of the design of steam engines, but the genius of James Watt wrought vast improvements, as this engine in the College grounds (built by James Watt & Co., of Soho, and supplied to the South London Water Works in 1850) can demonstrate.

The 2,000-word agreement, beautifully written on parchment, contains no stipulation of horsepower or speed, nor is the output of the pump specified. The cylinder was required "to have a diameter of 20 inches with a length of 3 feet," and all parts of the engine were to be "sufficiently strong to work with steam in the cylinder at 20 lbs. pressure per square inch." The connecting rod, crankshaft and pumps rods were to be of wrought iron. The Cornish boiler was built up of wrought-iron plates, and as it was not possible for them to be rolled sufficiently wide, the makers had to rivet a joint across each of the end plates. There is only a single row of rivets for both longitudinal and circumferential joints. The beam is supported over an entablature carried on six columns, whilst the ornamental bedplate contains the condenser and air-pump. The main pump and its air vessel were fixed in a well immediately below the crank shaft. The various sections of the flywheel are carefully dovetailed into each other to withstand the centrifugal stress.

The governor controls a butterfly valve at the inlet of the cylinder by means of a square iron bar inside one of the top castings. The bar rests on knife edges fixed at either end and is rocked as the governor balls rise or fall. A lever at the other end

MODEL WORLD

Photographs for Items of Model-Making Interest



A comprehensive gauge 1 layout. The water tower is a working model for use with internally fired locomotives.

of the bar connects to the butterfly valve. The valve gear of the cylinder comprises an early type long D valve driven by a single eccentric with the braced rod characteristic of all Watt engines. I might write much more about this engine, but space does not permit. Should any reader visit Loughborough College I would recommend him to examine the locking device for the nuts on the bearings of the beam trunnions, the blacksmith's work on the eccentric and pump rods and the mercury gauge. It is fitting that this College, whose primary object is the training of the young engineer, should possess an engine designed by the world's greatest engineer.

"00" Gauge

Returning to the model world again, the other day, I saw one of the latest developments in "00" gauge, a breakdown crane truck outfit. This is another novelty produced by Trix Ltd. in their efforts to keep the Twin Trains running as strongly as ever through the black-out. From the photo you will see that one 'Engineer's Department truck carries the crane and a second vehicle acts as a rest for the crane jib and also carries the dummy tool-box. An advantage of this novelty is that the crane can be moved from the truck and fitted on to a special base as shown in the rear, on the platform side, or more usually in the goods yard. The crane is die cast throughout and has a cut gear wheel, brass pulley and drum, and is actually an efficient working model.

African Village Model

The thought on miniature railways brings to the mind a well-known champion of "00" and "H0" gauges, the Rev. E. Beal of Dundee, who has written several books lately on the subject. I had a letter from Mr. Beal the other day and he sent me photographs of a most ingenious African Village Model which he constructed in the short space of a fortnight for the recent F. M. Exhibitions of his church at Kilmarnock and Paisley. The scale of this model is 4 m.m. to the foot and the baseboard folds in the middle and entirely closes up for transit with the aid of a flap at the end. The scheme represents on one side of the stream a heathen village with cattle kraal and chief's hut, and several huts for his wives and children. On the other side of the stream there are the usual evidences of a Christian mission post—school, classrooms, boy and girl boarder huts, grain silos, playing fields, etc. The church Mr. Beal explains has to be accommodated on the other side, hence the foot-bridge. Certainly an attractive piece of craftsmanship and a model with a mission.

Model Steamer

Liners vary in their detail, but generally by their deck detail a shipping man can tell them. What would you say of this picture—a model, of course—cargo steamer or luxury liner? She is a mixed express goods traffic and passenger liner plying the southern seas. Such a liner always has large open sports decks and nearly always an outdoor swimming pool with verandah café, and for the practical side of the work a plentiful supply of king posts with derricks for handling cargo, where harbours are not so well equipped as in more frequented sea routes. Quite often the ship has to remain outside her port, due to shallowness, and the goods have to be loaded into lighters for conveyance to or from the shore. This picture as I said before is of a model and is a nice piece of detail work, but owing to war regulations I am not able to give the name of the prototype or where she operates.

Comprehensive Display

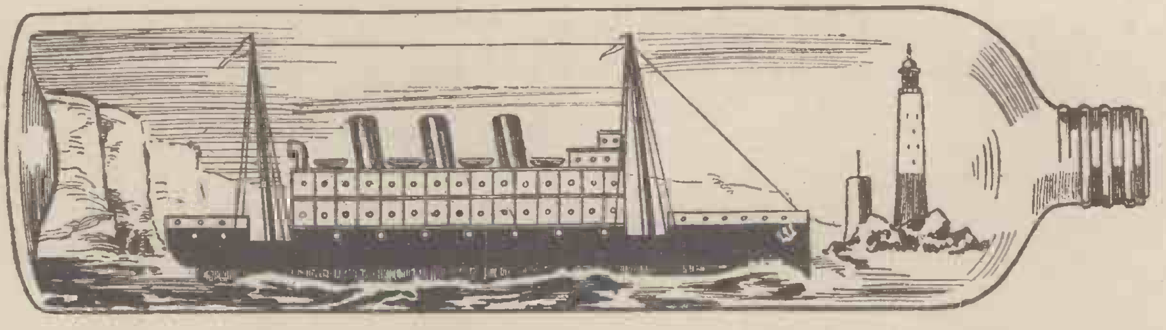
Visiting the North of England I took the opportunity of calling on the Manchester branch of Bassett-Lowke, Ltd., at 28 Corporation Street. Although similar to their London premises I find they have a more comprehensive display, comparatively, of models other than Bassett-Lowke productions. I was quite amazed at the variety—Frog Penguin sets, Astra searchlights, working models of army equipment, Meccano Dinky toys and the latest kits of Studiette and Lines Brothers. For the model engineer they have Myford lathes, Portass lathes, Stuart Turners range of engines, and in model railway equipment they stock the products of the Leeds Model Co., Mills Bros., and the "00" gauge buildings of Hailey Models.

Gauge 1 Layout

Gauge 1 railways, when space permits, have certainly a boldness of appearance and when in steam, an ease of manipulation which improves on gauge "0" and smaller gauges. Here is a photograph sent to me by Mr. Jos. C. Robinson of Rhyl, who has a comprehensive gauge 1 layout.

The water tower is a working model for use with internally fired locos, which have provision for replenishing the boiler and the fuel tank whilst the engine is in steam. The brick tower was made by Mr. Robinson himself from his own drawing, and is constructed from wood and covered with brick paper. The tank was made to the owner's dimension by Bassett-Lowke. It is of brass and divided into two compartments, one for spirit and the other for water. Trackside accessories like this make all the difference in the "life" of a model railway.

(Left) — The deck of a model steamer. (Right) — A model of an African village



Model Ships in Bottles

Although it Appears Impossible to Build a Model of a Ship Inside a Bottle, this Article tells you How Simple it Really Is

A MODEL of a ship in a bottle often puzzles, yet always appeals to everyone. It takes very little time to make, costs but a few pence, yet if made for sale will sell readily at a good price. The materials required are as follows: several lengths of stout wire, some odd scraps of wood, putty, quick-drying enamel or paint, and a bottle either of the round or square variety. If possible, a square bottle should be used, owing to the shorter neck. The parts are passed into the bottle by means of a length of wire with a needle firmly attached to it. Another length of wire with a $\frac{1}{2}$ in. of end bent is used to form the rake which pulls the parts into position when they are in the bottle. At least two lengths are required for the brushes; tufts from an old clothes-brush answer very well, being secured firmly with thread. The ship consists of the following parts: the hull, the body, the top, masts, sternpiece and fo'c'sle pieces.

The Hull and Masts

The length of the hull is $5\frac{3}{4}$ in. by $\frac{1}{2}$ in. square. A glance at Fig. 1 should make its construction quite clear. Holes are drilled through for the rigging, and two holes are bored from the top to the bottom so that the foot of the mast can be secured with wire.

A hole is also bored at the bows to take the mast stay. Two masts are now required, each being $1\frac{3}{4}$ in. by $\frac{1}{8}$ in. diameter. Two holes are then bored in each, as shown in Fig. 2, the upper being for the rigging and the lower for securing them to the hull. Secure the masts to the hull with wire as shown in Fig. 3, and pass a length of cotton through the left-hand hole of the hull through the mast from the back to the front, down through the right-hand hole in the hull, up again, through the back to the front of the mast, down to the starting place and draw taut and knot.

Fig. 1.—Details of the hull

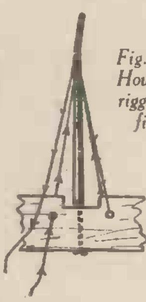
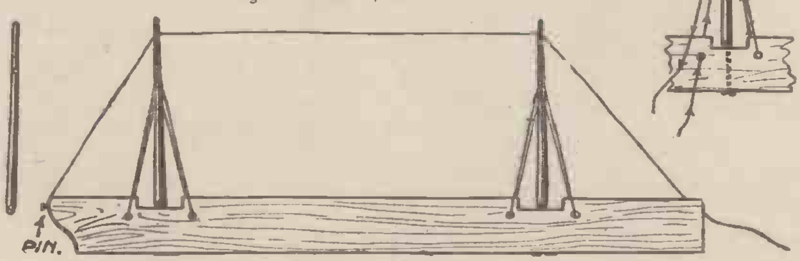


Fig. 3.—How the rigging is fitted



Figs. 2 and 4.—(Left) The masts, two of which are required, with holes bored for the rigging and for securing it to the hull. (Right) The hull with masts and rigging attached

The Mast Stay

Having wired on and rigged the masts, the next step is to put on the mast stay, which consists of thread or silk cotton. This is done as shown in Fig. 4, and the masts can now be raised or lowered, the rigging remaining taut. Care must be taken that the mast stay is sufficiently long enough to grip the outside of the bottle. If the mast does not lie flat a piece can be cut from the hull, which can afterwards be covered by the stern piece and body.

The body is made from two strips of wood 3 in. by $\frac{5}{16}$ in. by $\frac{3}{16}$ in. and three strips of very thin cardboard 3 in. by $\frac{1}{2}$ in.; these are glued together with the cardboard at the top and bottom and the remaining piece of cardboard dividing the wood in the centre (Fig. 5). (The edges of the cardboard overlapping the piece of wood may be sewn if desired, though it is not essential). If sewn the cotton becomes stiff after painting and appears like rails. Dots may be added to give the effect of the portholes.

The Top and Funnels

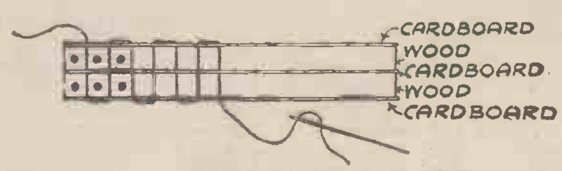
The top is made from a strip of cardboard the same size as the body, and to this is fitted the bridge, boats, ventilators and funnels. These are all glued on to the top, excepting the funnels which are placed separately in position in the bottle. Matchsticks are suitable for the boats, while pieces of lead pencil will do for the funnels, the length of which are $\frac{3}{4}$ in. There now remain the stern and fo'c'sle, which are small pieces of wood shaped to the bow and stern respectively. A small notch is then cut in the stern piece to allow for the mast stay, the object being to raise up the fo'c'sle and stern.

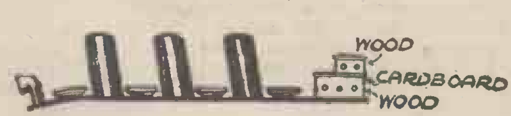
Small hatches, etc., may be added if desired. Figs. 7 and 8 show the shape of the stern and fo'c'sle pieces.

Preparing the Bottle

Obtain a square bottle if possible, thoroughly clean and dry, and paint the bottom and end blue. The land is painted green, great care being taken that the brush does not touch the front of the bottle nor the front half of the top, as the whole view is obtained here, the remainder being the background. Unless the bottle is painted the putty will show white underneath when the bottle is turned over. When dry, the putty should be put in piece by piece and spread over the bottom with the rake, spreading out very thinly and making a sloping design to represent the land. As soon as the putty is in, paint the sea blue; a few dabs of white added

(Continued on page 287)





Figs. 5 to 8.—(Top left) How the body of the ship is sewn together. (Below) Details of the bridge, boats, ventilators and funnels. (Above) The stern and fo'c'sle pieces

SMALL ELECTRIC FURNACES

By A. H. Avery, A.M.I.E.E.

Every Fitting Bench Should Have a Small Furnace of its Own, Ready for Instant Use, Similar to those Described in this Article.

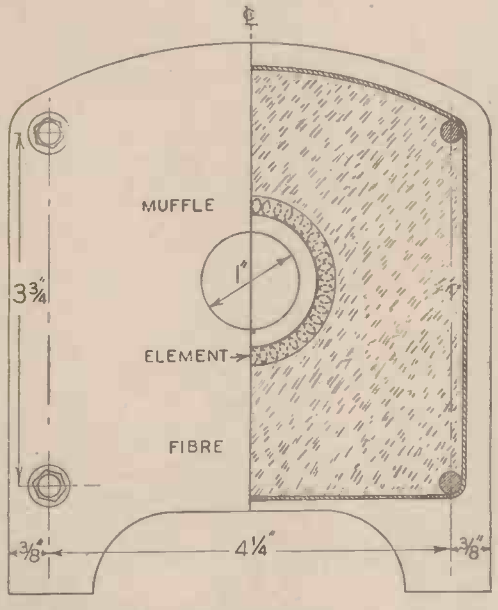


Fig. 1.—An end elevation in part section of a 200 watt electric furnace

THE employment of large electric furnaces in the iron and steel industry is well known and plays an ever-increasing part at the present time in our production of munitions. As a supplement or even a rival to the more or less familiar gas and oil-fired furnaces used by tool-makers and many other mechanical trades the small electric furnace is now becoming much more popular than formerly. Even in the smallest establishments more and more uses for this handy and reliable source of heat production is beginning to find favour, as well as in the amateur workshop. Its simplicity, flexibility and freedom from fire risks makes a strong appeal, and although its first cost may be slightly higher as compared with coal gas and blowpipe methods, it has everything else in its favour, particularly on the point of certainty of results, since temperatures can be controlled to a nicety and regulated to any pre-determined degree.

Hardening Tools

The application of the small electric furnace to a variety of different industries is almost unlimited, now that public electric supply is available so universally, but the one purpose for which it is pre-eminently fitted, namely hardening annealing, or tempering small tools is alone sufficient to commend it to the attention of all engineering and practical mechanics for the variety of repair jobs which are sure to arise in their daily work. Turners, fitters, and toolmakers all know the need for the quick-repair of "casualties" that occur, even in the most careful hands, such as drills, taps, lathe tools, screwdrivers, etc. An urgent job often gets held up inconveniently awaiting the issue of replacements from the stores, many of which are a quite unnecessary expense when the breakages could be re-conditioned so easily on the spot.

Materials

At the cost of a very few shillings it is within the ability of any mechanic to build up a perfectly serviceable electric furnace of sufficient size to deal with the heat treatment of either carbon or high-speed steels up to ¾-in. diameter rounds, or ½-in. squares. The necessary material used in its construction is tabulated in the following list:

- 2 pieces of "Sindanyo" electric arc and heat-resisting board, ⅜ in. thick for the ends.
- 1 piece sheet iron 22 SWG for the body.
- 4 lengths of ¼-in. diameter bright round mild steel for bolting up studs.
- 8 hexagon nuts and washers for ¼-in. studs.
- 1 fireclay former or muffle, as used in 500-watt electric bowl fires, with 1-in. central hole 3 ins. long, grooved externally to receive the resistor winding.
- 60 ft. of No. 32 SWG nickel-chrome 80/20 per cent. wire for the spiral heating element or resistor.
- 1 3-terminal china connector, 5-amp size.
- 4 ft. of 3-core 23/.0076 "Varnoflex" flexible for external connection to plug point.
- 2 lbs. of "Newtempheit" fibre for heat insulation or lagging.
- 1 lb. "Tringle V" No. 29 Alumina cement for covering the resistance spiral when wound.
- 1 lb. "Pyruma" putty for sealing any apertures not wanted.

The above materials are suitable for furnaces where the maximum temperature required does not exceed 850 or 900 deg. C. such as required for hardening carbon steels. But if special high-speed steels are likely to be dealt with, the heat treatment is on a higher scale needing a more refractory type of muffle and resistor winding. In such cases the specification for the muffle is "Sillimanite," a highly resistant form of alumina, while the use of "Kanthal" wire is necessary in place of 80/20 per cent. nickel-chrome. Temperatures up to 1,200 deg. C. can then be obtained with safety.

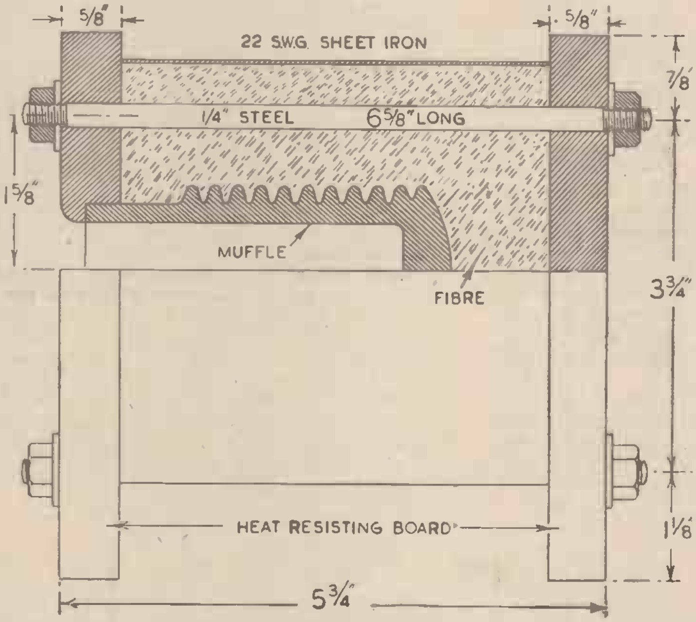


Fig. 2.—A side elevation in part section of a 200 watt electric furnace

Arrangement of Parts

A general idea of the construction and arrangement of parts is given in Figs. 1 and 2, representing end and side elevations of the furnace in part section. The Sindanyo asbestos cement compound used for the ends will no doubt be familiar to many as a favourite material for small switchboard panels, in place of the enamelled slate and marble formerly in vogue. It is a material quite easy to drill, can be cut to shape with a hacksaw, filed and turned, and is very resistant to high temperatures. The sheet-iron body has an overlapping seam at the bottom, where it is riveted or spot-welded according to facilities at hand. The long bolts nutted and washered at either end, call for no comment, the dimensions being taken from the drawing. The holes in the end frames drilled to receive them are marked out in such position as to locate the sheet-iron body against which the end frames butt.

So far the work is of a very simple character. The part requiring considerable care is the preparation of the wire spiral or "resistor" which forms the heating element, and lies embedded in the grooves on the exterior of the muffle. The gauge and length of wire used for this depends, of course, upon the voltage of the circuit upon which it will be used. In the majority of cases this will lie somewhere within the limits of 200 and 250 volts, and separate specifications to cover this range are given below. In practice it is found that with heat insulation of the thickness and material here adopted a final temperature of 850 to 900 deg. C. results with a loading of 180 to 200 watts on the resistor coil. This is the equivalent of a current consumption between 0.78 and 0.87 amperes on the standard 230 volt service. The final temperature of embedded conductors is a very difficult matter, either to calculate or to estimate, as in the furnace the radiation of heat is determined by the immediate environment and the nature of the lagging employed. The figures recommended above, however, have been obtained from actual extensive running tests, and can be relied upon. The results, too, will be unaffected by the nature of the current, the windings being "universal" in the sense of being equally suitable for either alternating or direct current service, provided the voltage is similar.

Heating Coil

The special alloy of nickel and chrome used for the heating coil contains 80 per cent. of nickel and 20 per cent. of chromium which resists to a high degree oxidisation and scaling at high temperatures. Like most other resistance materials it possesses a positive temperature co-efficient, the resistance for a given length increasing as the temperature rises, so that allowance for this feature has to be made in the calculations of length required to result in a definite loading in watts. Unfortunately, this rise in resistance is not constant for equal increments of heat, but follows a rather erratic course which is indicated by the curve plotted out in Fig. 3. Here the percentage increase in resistance between temperatures of 20 and 1000 deg.C. is shown. To apply the curve in practice the cold resistance is first obtained from makers' tables for the wire in use, and this figure added to by the appropriate percentage-increase as set out in the curve, for the final working temperature. For example, to find the resistance of 50 ft. of No. 19 SWG 80/20 per cent. nickel-chrome at a temperature of 900 deg.C. first ascertain the resistance per ft. cold (i.e. at 20 deg.C.) from tables, and multiply by the length in ft. Thus, No. 19 SWG has a cold resistance of 0.387 ohms per ft., so that 50 ft. would have a resistance of 0.387 x 50=19.35 ohms at 20 deg.C. Reference to the chart in Fig. 3 now shows that there is an increase in resistance of 4.15 per cent. at 900 deg.C., thus the original value of 19.35 ohms when cold becomes 20.15 ohms when heated to 900 deg.C. since:

$$19.35 + \frac{19.35 \times 4.15}{100} = 20.15 \text{ ohms.}$$

Any other gauges or temperatures can be dealt with, of course, in the same way making the necessary correction with the aid of the percentage increase in resistance shown by the above curve.

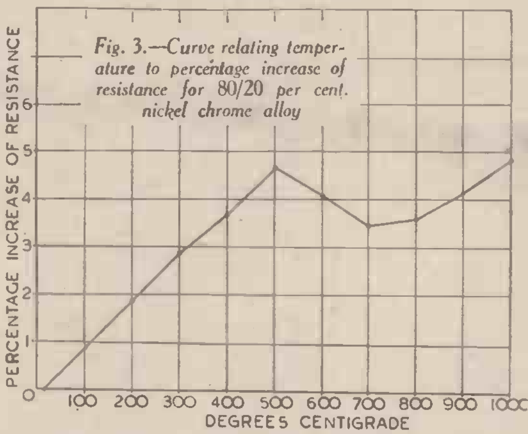


Fig. 3.—Curve relating temperature to percentage increase of resistance for 80/20 per cent. nickel chrome alloy

Fireclay Muffle

The form of fireclay muffle employed in this furnace has an external groove or thread to receive the spiral heating coil. This coil is close-wound on a mandrel consisting of an 18-inch length of No. 12 SWG silver steel wire, the overall length of the spiral being determined by the voltage of the circuit it is used upon. For circuits of 200 to 210 volts the overall length required is 14¾in.; for 220 to 230 volts 16 ins. long; and for 240 to 250 volts 17¾ ins. long. In each case the gauge of the resistance wire is the same, namely No. 32 SWG nickel-chrome—known in the trade as "Brightray." When "Kanthal" wire is used for the higher temperatures one gauge larger will be called for, namely No. 31 SWG. Winding this spiral is not a difficult matter when due precautions are taken. The wire is extremely hard and springy, so that it will need winding under considerable and constant tension, and above all it must be free from any kinks or other defects. If the tension is varied during the winding the turns of the spiral will not be all of the same diameter, so that the safest plan is to make a spring tension-head through which the wire passes on its way to the mandrel. Usually the winding is done in a lathe, and when the coil has been completed the two ends on either side of the cut portion must be held firmly, or a tangle will result when the wire is divided. Holding the coil on the mandrel at the free end, allow it to revolve slowly until it has relieved its own tendency to unwind, after which it is slipped off the mandrel with care, so that the turns are not distorted. It is next pulled out by stretching the ends apart until about 3 feet long, ready to wind in the grooves on the muffle. The end-to-end length of the groove is rather more than three feet, so the coils will be still under a slight end tension when they are laid down, which ensures their even and close contact with the muffle.

Anchoring the Spiral

Provision has now to be made for anchoring the ends of the spiral. Twist up a couple of nickel-chrome wires of the same gauge into two pigtails about a foot long, and secure them with one turn round each end of the muffle to make the leads in and out. Straighten out a foot or so of the heating spiral at each end, and, giving one of these a few turns round the twisted pigtail to anchor it, lay the spiral heating element carefully in the grooves with even tension, so that individual turns all lie the same distance apart. The finishing end of the spiral is then anchored to the other twisted lead in the same manner as at the start. Each double lead with the straightened end of the spiral attached to it should then form a 3-strand connection for attachment ultimately to the china connector and flexible lead-in wire. Be particularly careful to keep the individual turns of wire in the heating spiral as evenly spaced as possible, otherwise those closest together will get hotter than the others.

Cement Coating

Two good coats of the Alumina cement are then to be given to the whole of the exterior, after previously closing any holes in the fireclay former with Pyruma putty. The cement coating is necessary to prevent the lagging from coming into actual contact with the hot resistance wire, which might otherwise fuse it or set up chemical action. Mix the dry cement powder into a thin paste with clean cold water, and work it well in between the spirals with a brush until the whole is thoroughly covered. It should stand in a warm place for a day or two and can then be finally dried out by passing current through the winding itself until a red heat is reached. The 3-strand leads coming from each end of the winding are further protected by stringing over them "Fishspine" or "Ballsok" insulating beads to the point where their ends are finally twisted up with the copper flexible from the outer circuit, the junctions being pinched by the screws of the china connector. The joint is made just inside the rear end cover through which the outer connection passes to the plug point. Varnoflex or asbestos-covered heat-resisting flex is better to use for this purpose than rubber insulated flex as it will be subject to a certain amount of heat. Either 2-core or 3-core flex can be used, the latter being necessary if Home Office requirements are complied with; in the latter case the third strand is attached to the iron body of the furnace by a small screw and nut.

For the lagging between muffle and outer body there is choice of several materials, all of which are serviceable to a certain point. The risk of fusion at high temperatures must be guarded against, however, and the electrical insulating properties of some are not too good. The material recommended here, known as "Newtempheit" appears to be as satisfactory as any and better than most. No chemical corrosion has been noticeable upon the wire resistor windings, a point which needs carefully guarding against, hence the cement covering to the spiral as an additional precaution. To apply the lagging mount the front end frame flat on a bench, having previously inserted the four long studs and placed the metal body over them. The open end of the muffle, with its resistor winding, is then socketed into its recess, the bead-insulated leads being brought up along the sides next to the metal body, as far away from the muffle as possible. The lagging can then be dropped into the casing a little at a time and pressed firmly down without disturbing the position of the muffle or the bolts. When the casing is nearly full, cut the excess from the leads and joint them to the outer flexible by twisting tightly together. The pinch screws in the china connector will then make a firm joint. Finish packing with lagging until level with the end of the metal body, thread the rear end plate over the studs, and pull the whole firmly together with the end nuts. A standard 2-pin or 3-pin 5-ampere plug enables connection to be made between the furnace and the service by an appropriate wall socket. Even a lampholder adapter may be used if preferred, as the current is so small, amounting to little more than the requirements of three ordinary 60-watt lamps.

In Use

For the first time or two when put into use there may be a slight amount of moisture ooze from the interior, as the lagging is slightly hygroscopic. This, however, soon dries out and gives no trouble in practice. Remember when using the furnace, that time must be allowed for it to acquire its full heat, as the temperature rises gradually from the moment when it is first switched in, until a point is reached where loss of heat by radiation balances gain of heat from the coil. In a furnace of this size full heat is usually reached in 20 to 25 minutes from first switching in, after which tools of ¼-in. diameter will take only about 3 minutes to bring up to hardening temperature, or five to six minutes for tools ½-in. square.

In carrying out repairs to carbon-steel tools, such as ordinary taps, drills, or other sundries the steel must be first softened to a degree enabling it to be easily shaped up. It is placed, therefore, in the muffle when fully hot and current switched off and left

(*Continued on page* 287)

MASTERS OF MECHANICS

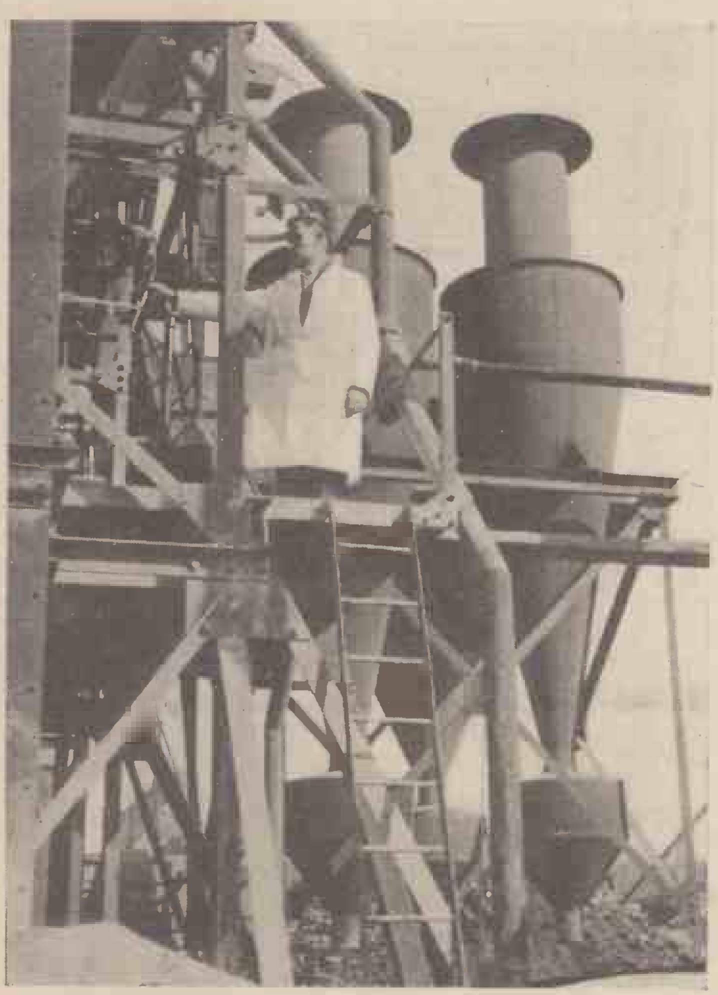
No. 54.—EARLY IRON-SMELTING IN ENGLAND

The Deeds of Dud Dudley, a Pioneer of the British Iron Industry

IRON, in its many forms, is the chief material of engineering. Without this most useful of all metals, modern industrialised civilisation would have been impossible of attainment and even the agricultural arts, through lack of machinery, would still be in the backward state in which they were centuries ago.

Yet although iron is, nowadays, the cheapest and the commonest of metals, this abundancy of the metal did not always exist. Time was when an article made of iron, such as a ploughshare, a sword or a cooking utensil, possessed a very great value. This was because not only was iron found to be difficult to smelt from its ores but, also, because it could only be produced in relatively small quantities at a time and with a great expenditure of materials.

Steel was, of course, unknown in very early times. The iron which the Roman invaders manufactured in Britain in the days of the imperial Caesars was more or less wrought iron, and, indeed, right up to the beginnings of the engineering industry in England this was the only variety of the metal which could be obtained commercially



Upon Dud Dudley's pioneering discoveries is fundamentally based the modern iron industry, without which the present-day intricate industrial plant and equipment could never have been brought into being

Charcoal

Through the centuries, ironmaking in England was undertaken on the village industry scale. Charcoal was considered to be the indispensable ingredient for iron making, and as vast quantities of charcoal were needed for the process it was found advantageous to take the iron ore to the well-wooded districts of Britain from which the charcoal could be obtained on the spot rather than to carry the necessary timber for charcoal production to the locality in which the iron ore was obtainable. Hence it was that the Romans made iron in the Forest of Dean (some of their workings are still visible there) and that our medieval ancestors manufactured their iron for swords and for ploughshares, as well as for domestic utensils in Sussex and, later on, in other parts of the country.

The medieval process of iron production consisted merely in mixing a small quantity of iron ore with a relatively large amount of granular charcoal and by subjecting the mass to the highest temperature obtainable. In these conditions the carbon (i.e. the charcoal), having a great affinity for oxygen, abstracted that element from the iron oxide which comprised the natural iron ore. As a result, the metallic iron was left behind and it was found (in small quantity—for the process was wholly inefficient) at the bottom of the furnace when the latter cooled.

"Devour the Woods"

During the course of time, iron-smelters set up their furnaces up and down England, mainly in the well-wooded districts, in order that they might obtain abundant supplies of freshly-burned charcoal. The smelters, however, habitually made such demands upon the charcoal-producing timber that they gained for themselves a good deal of unpopularity, both official and private.

At one time the Government took drastic steps and prohibited the smelting of iron anywhere in England, but the futility of this step became eventually recognised, so that, in later years, iron production by means of charcoal (to the detriment of the English timber resources) began again with even greater vigour in our country.

In the latter half of the seventeenth century, the best iron came from Germany, for in the many forests of that country charcoal was abundant, and the peculiar quality of the iron ore obtained by the Germans seems to have rendered it well adapted to the gentle smelting process which was brought about by the assistance of charcoal.

One of the German smelters came to England during the latter part of the seventeenth century. His name was Simon Sturtevant, and he seems to have been possessed of the notion that coal could be made to take the place of charcoal in the process of iron smelting. Sturtevant was even granted an English patent in order to "neale, melt and worke all kind of metal oares, irons, and steeles with sea-coale, pit coale, and earth-coale," but his process, when tried out on a large scale, failed signally, and accordingly his patent was cancelled before it had been in operation for a year.

Lord Dudley

About this time there lived at Dudley Castle, in the county of Worcester, one Edward, Lord Dudley, who had made a name for himself as an industrialist and as an owner of iron-smelting furnaces in the district. Lord Dudley, besides possessing a considerable number of legitimate off-spring, was the father of eleven natural children, of which latter, the fourth, who was born in 1599, and given the name of Dud Dudley, rose to a position of eminence in the iron world, despite the chequered and adventurous career which eventually became his.

The Earl of Dudley, seeing the inborn ability of his son, Dud, took the greatest pains with his upbringing, educating him carefully, and giving him a position in his iron works near the town of Dudley.

The latter town was at that time one of the centres of the English iron industry, although it mainly concerned itself with the production of small ironware, such as nails, keys, horseshoes, and a few common agricultural implements. Into this industry therefore the boy, Dud, was flung by his noble father in order to gain experience of the practical side of the business. Exactly what Dud Dudley did at this early stage of his career we do not know, but we do know that some years afterwards he was sent to study at Baliol College, Oxford, from which seat of learning he was eventually suddenly withdrawn by his excitable and somewhat eccentric parent in order that he might take charge of an iron furnace and a couple of newly-erected forges at Pensnet, in Worcestershire.

No sooner was the young Dud Dudley installed as manager of the works than he came up against the well-familiar problem of the increasing scarcity of charcoal supplies. Many methods were adopted by the young Dudley to eke out and to economise his supplies of the precious charcoal, but they were all of no avail.

Powdered Coal

Feeling, therefore, driven to desperate devices, Dudley took up (whether knowingly or otherwise is not known) the idea which had been first put forward by old Simon Sturtevant, the German smelter. He began to smelt his ore with powdered coal, and although at first some apparent success resulted from these trials, the iron which was obtained was of an exceedingly poor nature, since it had been contaminated with sulphur obtained from the coal and thereby partially sulphurised.

It was Dud Dudley's clear realisation of the part played by sulphur in the deterioration of the iron which put him on the right road to his epoch-making discovery—that of the use of de-sulphurised coal, or, in other words, coke, for smelting purposes.

To rid the coal of its contained sulphur, Dudley heaped it up out of doors in conical piles, after the fashion of charcoal-burning heaps, and set fire to it. The coal burned slowly, and in consequence produced the light, porous material which we nowadays call "coke," but which Dudley and his associates termed "char."

This "char" they proved to be practically devoid of sulphur. So they powdered it up, mixed it with the requisite proportion of carefully selected iron ore and smelted the mixture in their furnaces. The experiment worked, and worked amazingly well. Not only did the coke (or "char") readily convert the iron ore into its metal, but by its use it was found possible to employ larger furnaces, and these, reaching a higher temperature, made it possible to obtain a much purer iron than was ever available before.

It was in 1619 that Dud Dudley succeeded with the above experiments. In that year he managed to reach and to maintain an output of three tons per week of his new iron. And in that year also he wrote to his father, the Earl, detailing to the latter worthy all information concerning the nature and the success of his experiments, which information seems to have so delighted the heart of the energetic Earl that he immediately applied—in his own name, incidentally—to King James for the grant of a patent for the invention, which patent was forthcoming and was finally sealed on February 22, 1620.

New Furnaces

Dudley the younger at once proceeded with the erection of new furnaces both in Worcestershire and in the adjoining county of Staffordshire. These activities succeeded beyond his wildest dreams. The Dudleys—father and son—became known far and wide as the manufacturers (by a secret process) of an iron which even excelled that which was formerly imported from Germany.

The success of the Dudleys, however, was not allowed to go unchallenged. Rival iron-smelters presented a petition to the King in which they alleged that Dudley's iron was unworkable, full of impurities, and not merchantable. They stressed the fact that, in some unknown way, the metal was produced through the agency of coal, a material which King James regarded with great disfavour, and they ended up by saying that the Dudleys were ruining their trade since the latter individuals were able to produce the iron at cheaper rates than they could do.

The result of this petition was that Dudley was commanded to manufacture a quantity of his iron and to send it up to the Tower of London for trial. This was done with all celerity. Up to the famous Tower of London the new iron of the Dudleys went. It was put through many tests, cannons and other pieces of ordnance were made from it and it was pronounced "good, merchantable iron" which was "fit for the making of muskets, carbines, and great bolts for shipping."

It is sad to relate that after this victory over his detractors Dud Dudley had the misfortune to have his works at Cradley (Staffordshire) almost completely swept away by a great flood. Undaunted by this setback, however, Dudley at once began to erect new works and to turn out his "pit-coal iron" in even greater quantities than before. Again the neighbouring ironmasters petitioned the King on the score of Dudley's iron, but their combined influence proved of little avail, for all they succeeded in effecting was in obtaining an official restriction of the Dudley patent to fourteen years instead of to its original thirty-one years.

Cast-Iron Wares

Serenely, therefore, Dud Dudley continued to work his patent, and he "made annually great store of iron, good and merchantable, and sold it unto diverse men at twelve pounds per ton."

"I also," says Dudley himself, in the book which he subsequently wrote and entitled "Metallum Martis" (1665), "made all sorts of cast-iron wares, as brewing cisterns, pots, mortars, etc., better and cheaper than any yet made in these nations with charcoal, some of which are yet to be seen by any man (at the author's house in the city of Worcester) that desires to be satisfied of the truth of the invention."

Dudley, besides being able to produce iron more easily and more cheaply by means of coke-smelting, also evolved the technique of casting iron, i.e., of pouring the molten metal into moulds and of allowing it to solidify therein.

New Works Every Year

He erected new works every year, his largest one being put up at Hasco Bridge, near Sedgeley, and being capable of turning out some seven tons of iron per week. Almost as soon, however, as this works was got into full operation, the enraged ironmasters, charcoal-burners and other workers of the surrounding districts assembled in a mob and raided the works, destroying the furnaces and reducing everything in the immediate vicinity of the building to ruins. More than this, Dud Dudley was given no peace. He was personally attacked by rioters, and even when he managed to escape physical injury at their hands, he found himself harassed by the many and tedious trade law-suits upon which he was obliged to embark. Eventually, through a concourse of malign agencies, he found himself severely in debt, in consequence of which fact he was arrested, sent up to London, and jailed in a debtors' prison.

Released from Prison

It was King Charles I who released Dud Dudley from his debtor's confinement, but despite this act of clemency Dud's evil fortune still seemed to pursue him. The Civil War in England between the King's and the Parliamentarian forces broke out. Strongly loyalist, Dud Dudley ranged himself on the side of the King, and for the time he appears to have completely abandoned his iron works in Worcestershire and Staffordshire. Holding several official positions in the Royal army, including that of "Chief Military Engineer," he went unscathed through several fierce battles. Cannons and other guns were forged under his direction, but eventually the forces of the Parliamentarians under Cromwell proved the stronger of the two factions, and after a series of exciting adventures Dud Dudley was captured in Bosco Bello woods, near Madeley, from whence he was taken to Worcester Castle and imprisoned therein. In spite, however, of the fact that he was closely guarded the adventurous Dudley, aided by a companion, managed to escape from Worcester and he succeeded in reaching London. In that city, shortly afterwards, he was recaptured, at once recognised, and summarily sentenced to be executed by "shooting to death."

On the day before his intended execution—a Sunday morning, August 20th, 1648—Dudley and a fellow prisoner, taking their opportunity "at ten of the clocke in sermon time," again made their escape by dint of overpowering the few guards who had been left in charge of them. Although severely wounded in the leg, Dudley managed to drag himself on improvised crutches to Bristol, in which city he lived in secret until the hue and cry for him had died down.

A Project Wrecked

Whilst living in Bristol, Dudley succeeded in inducing two other Bristolians to enter into a partnership with him to recommence his process of iron manufacture. This project was taken up with great enthusiasm by the partners, but before long Dudley quarrelled with them, and so by his own stupidity, or perhaps irritability, wrecked a project which might have led him to enduring success.

After the eventual rout of the Cromwellian forces and the restoration of the Royalist regime under King Charles II, Dud Dudley at once petitioned the King for a return of his former possessions. There were many other loyal petitions from other people, however, and all Dudley obtained was a renewal of some of his former official offices. He failed to obtain a renewal of his patent for making iron from coal. Indeed, two or three other individuals were granted a patent for "iron-making with coale," but as Dudley alone knew the practical secret of iron production by means of "char" or coke, these other patentees and their businesses came to nothing.

Restored to his official offices (granted formerly to him by King Charles I) such as those of Lieutenant of Ordnance and Surveyor of the King's Armoury, and finding himself also through the new King's favour appointed to the position of Serjeant-at-Arms, Dudley seems apparently to have given up all desire of recommencing his once very flourishing iron-smelting businesses.

Dudley's Death

Instead, he began to lead a semi-retired life, devoting much of his time—outside his official and nominal duties—to the composing of his "Metallum Martis," a curious work in which he gives a history of his iron-making invention. From this time onwards (about 1665) we hear nothing further concerning Dud Dudley. All we know is that a few years later he retired to St. Helen's, a Worcestershire village, and that he died there in 1684, in the 85th year of his age.

Around the Trade

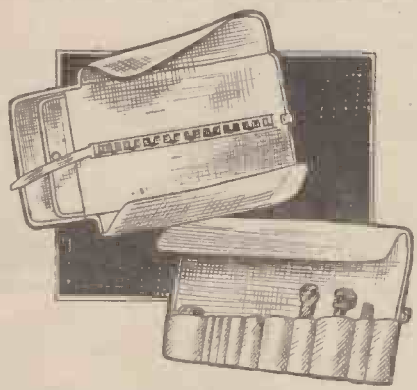
Items of Interest from the Manufacturers

A Compact Tool Roll

THE neat and compact tool rolls shown below are ideal for motorists and cyclists. They are both made with strong brown waterproof canvas and can easily be slipped into the pocket. In one case the tools are held in position by means of an adjustable looped leather runner strap, whilst in the other sewn-in pockets of various sizes hold the tools firmly in position. They are obtainable in various sizes.

Double Whirling Shower

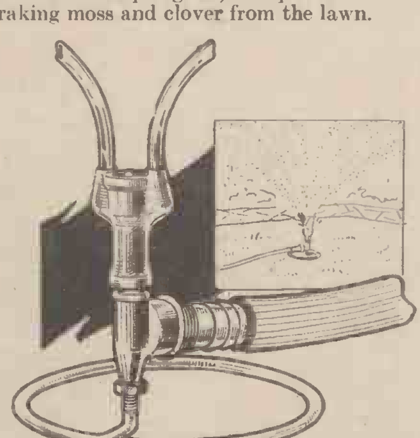
WATERING a lawn is rather a tedious task if one has to stand and hold the hose, but with the device shown on this page the job is considerably simplified. It is a double whirling shower which is fitted to the end of the hose, and the pressure of



Two types of tool roll that can be carried about in the pocket

water causes the two jets to revolve. In this way a large area is sprayed with water.

Whilst on the subject of care of the lawn, the rake shown at the foot of the page, known as a Springbok, will prove ideal for raking moss and clover from the lawn.



The use of this whirling shower will save considerable time and labour when watering the lawn

Combined Monocular and Magnifier

THIS interesting gadget will prove to have a number of uses as it can be used to view things at a distance (6 X magnification) or close up (9 X magnification). When used as a monocular the knurled wheel shown at the top of the device allows variable focus. It is supplied complete in a leather case.

A Pipe Ashsafe

SMOKERS will no doubt find a use for the pipe ashtray shown on this page which is fitted with a cork knockout. The curved rim, which can be taken out for easy

A combined monocular and magnifier

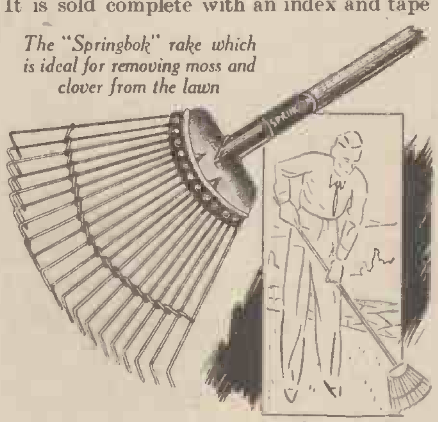
cleaning, helps to retain the smoke that gets underneath and it also keeps the ashes out of sight. It is obtainable in marbelite or bakelite, and the purchaser has the choice of three colours—green, walnut or mahogany. The ashtray, which can also be used for cigarettes, is unbreakable, and will not tip up when the pipe is knocked out.

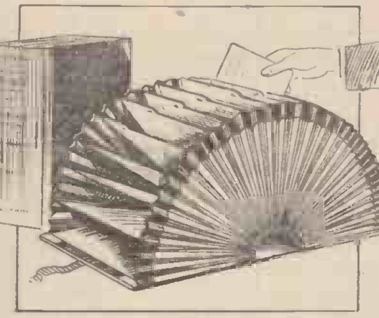
An ashtray for pipe smokers which is fitted with a cork knock out

"Taque" Expanding File

THE householder is no doubt often at a loss to find a safe place for bill receipts letters, etc., and the expanding file illustrated on this page should prove ideal for this purpose. It has cloth-bound backs and the pockets are made of strong manilla. It is sold complete with an index and tape for tying, and is obtainable in octavo, quarto, and foolscap sizes.

The "Springbok" rake which is ideal for removing moss and clover from the lawn



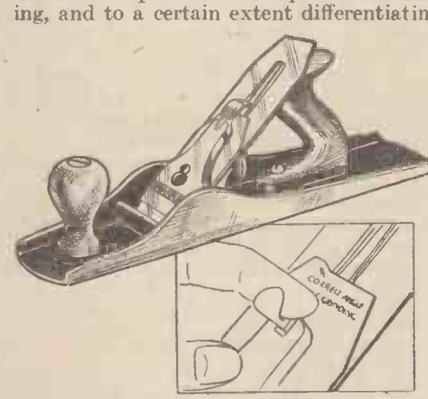


An expanding file which is suitable for household use. It can be used for filing bill receipts, letters, etc.

Reflex Document Paper for Copying

WE have recently carried out tests with a sample of Ilford reflex document paper submitted to us by Messrs. Ilford, Ltd., of Ilford, London, and we have obtained very satisfactory results. In this method of photographic copying, there is no need for a camera, the sensitive side of the photographic paper merely being placed in direct contact with the original and then exposed to any convenient source of light. The light is actually directed on to the *back* of the sensitised paper, so that it passes through the sensitive layer, reaches the original and is reflected back by the white paper, but is absorbed by the black image. In this way a reflex negative is formed, and from this any number of positive prints can subsequently be prepared.

This system of reflex copying is suitable for use with any form of original consisting of lines, such as a drawing, written or printed matter, printed illustrations, etc. Usually, such subjects are on a white base, but this is immaterial, because the paper we tried out proved to be capable of recording, and to a certain extent differentiating between a wide range of colours. Consequently it is suitable for copying all types of drawings and record cards on which coloured inks have been employed.



An all-metal jack plane which will make a useful addition to the handyman's tool box

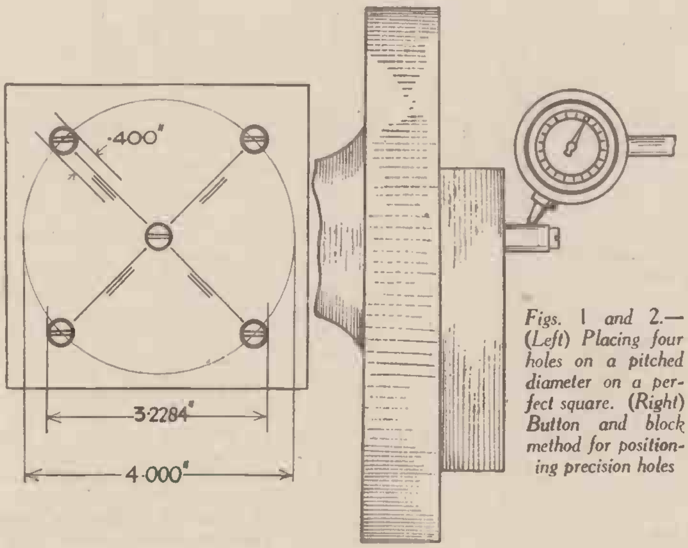
All-Metal Jack Plane

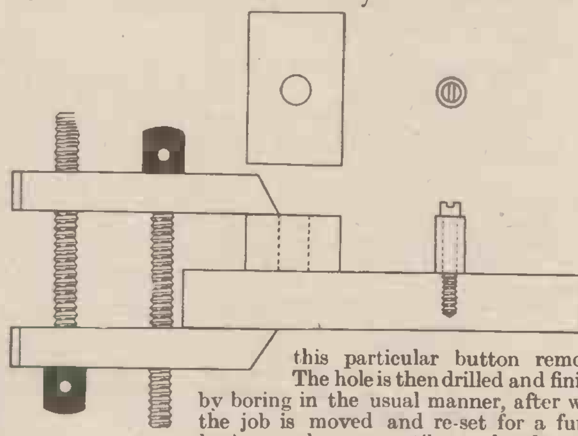
THE handyman is always on the look-out for efficient tools, and the all-metal jack plane shown herewith will prove a useful addition to his tool-box. The advantage of the plane is that it cannot warp, and the cast steel frame will ensure highly finished work. It is fitted with a mechanical vernier screw adjustment which allows the iron to be finely adjusted. The angle of the plane may also be adjusted to facilitate the planing of end grain.

THE USE OF

Buttons in Engineering Practice

Ensuring Accuracy in Component Parts of Intricate Mechanisms so that Assembly can be Carried Out by Unskilled Men





Figs. 1 and 2.—(Left) Placing four holes on a pitched diameter on a perfect square. (Right) Button and block method for positioning precision holes

TO enable factories to employ young and unskilled labour on the assembly of intricate mechanism tends to show that the component parts must be correct in every detail, also that the most important feature is the holes. To facilitate the assembly of engine parts they are usually finished to within a tolerance error of .001 in., excepting such parts as bushes and ball-races, the accuracy of which must be finer still.

With electrical parts the assembly holes to accommodate screws, pins, etc., are usually to within position limits of .002 in., but hole diameters in the majority of cases have to be within finer limits. It will be visualised from the foregoing statement that the tools and jigs which are to produce the holes must be of greater accuracy than that required on the component parts, to allow for minute variation in production. Many and varied are the appliances and machines invented and marketed by nearly every country in the world to ensure holes being put in the place that they are required to be.

Accuracy of Holes

The accuracy of holes in tool-room work can be divided up into four classes, e.g. holes that have to be within .0005 in. of a predetermined position and size, which can only be bored with a jig-boring machine. The next group are those that can be within a margin of .001 in. If a jig-boring machine is available, these are also decidedly better produced by this method, but many engineering works and tool-rooms are denied these special luxuries, and so have to resort to simpler and less expensive operations, the most commonly known method being the use of buttons. These little instruments consist of short pieces of round cast steel hardened and tempered to restrict bruising and wear. They are usually supplied in sets of four, the smallest set being .2 in. in diameter, then increasing by .1 in. per set up to 1 in. The size of them is not particular, provided they are perfectly round. Each one is provided with a clearance screw hole which requires to be $\frac{1}{64}$ in. larger than the screw which it is to accommodate, to allow of movement in setting. It is really a turner's method of boring precision holes, and the sequence of procedure is as follows: The holes are carefully marked off with the vernier height gauge, and centre-pop marks indented in the spot where the holes are going to be. The holes are then drilled and tapped to a suitable size to accept screws which will pass through the buttons and fasten them on to the job which is going to be bored. Assuming that four holes have to be placed in a perfect square on a pitched diameter circle (P.D.C.) to within a limit of one-thousandth of an inch (.001 in.); five buttons would be used, one would denote the centre line, which would not be bored, and the remaining four would define the position for the holes (Fig. 1). The five buttons would be screwed on to the job and adjusted to their exact position with the micrometer of a suitable size after the necessary calculations had been made. Again assuming that the four holes are on a 4-in. diameter circle and the buttons are .400 in. diameter, the length of chord being given as 2.8284, add to this the diameter of one button, which will then be 3.2284, and this should then be the dimension outside any two buttons forming the square when measured with the micrometer. If they are not so, they are gently moved into position, after which the screws are made snug and tight before being mounted on the lathe face plate for boring.

A dial indicator is really a necessity to set the job up to the accuracy required, but failing this instrument the only thing possible without fear of moving the buttons is to lightly colour them with Prussian blue, then, using a very thin hooked scriber, obtain a marking, rotating the lathe by hand, then adjusting the job into position. After it has been ascertained that the button is in true alignment with the lathe centre line by the indicator reading "steady" when the machine is revolving, the clamps holding the job on to the face plate are finally tightened. The screw holding the button in position is then withdrawn, and this particular button removed. The hole is then drilled and finished by boring in the usual manner, after which the job is moved and re-set for a further boring, and so on until completed.

Button and Block Method

It will be realised from the foregoing that the process already outlined being rather lengthy has its economic limitations, and for this very reason many boring machines costing vast sums of money have proved a commercial proposition. It may be of some interest to learn that there is another and more profitable way in which buttons can be used for positioning holes, this being known as the "button and block method." It is considerably quicker and use can be made of the drilling machine, instead of the lathe. It is quite as decisive, especially if the holes are of dimensions which allow the use of standard reamers. A glance at the illustration (Fig. 2), in conjunction with the explanation, will help to convey the process satisfactorily. Buttons are made of a suitable size similar to those already outlined, hardened and tempered, afterwards ground if possible, but should this not be so, they can be either made from standard size silver steel or turned to some size previously decided. A block of cast steel is obtained as illustrated, and a hole placed somewhere near the middle, into which these buttons are a *slide fit*. Exactly the same procedure is adopted as with the previous button job in regard to getting definite position with the micrometer, but when all are set and tight, the block is slipped over one of the buttons, and then very firmly clamped on to the plate or work-piece requiring to be drilled. The screw retaining the button is then withdrawn, and the button pulled out of the block. It is then merely a matter of transferring this hole right through into the job, and if this is done with care there is no reason why it should wander, as the block will act as a jig in guiding the drill and reamer. It is preferable if the block is hardened and tempered before use to minimise wear, which will naturally result in the hole becoming larger.

QUERIES and ENQUIRIES

A stamped addressed envelope, three penny stamps, and the query coupon from the current issue, which appears on page iii of cover, must be enclosed with every letter containing a query. Every query and drawing which is sent must bear the name and address of the sender. Send your queries to the Editor, PRACTICAL MECHANICS, Geo. Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2.

Covering a Floor

I AM desirous of covering a floor with a composition flooring such as "Litosilo." Could you possibly tell me the mixture and quantities of such a composition, also where the materials may be obtained?—A. M. (Liverpool).

FLOORING preparations of the type you name have compositions which are kept secret by the manufacturers. Essentially, however, such preparations contain powdered barytes (barium sulphate) mixed with shellac varnish and often a small proportion of linseed oil. Such "lino" compositions, when brushed over a smooth flooring surface, set hard fairly rapidly, drying with a good gloss and giving a hard, water-repellent surface.

Since (as we have mentioned above) these compositions are more or less maintained secret, we cannot give you the exact proportions of their ingredients, but from the information contained in the preceding paragraph, we feel sure that, after a few trials, you will be able to make a satisfactory flooring composition for yourself.

The materials necessary may be obtained from any large paint and oil stores.

Making Film Cement

I WISH to make my own film cement for nonflam film of any make. I believe the cement consists of four things, namely acetic acid, amyl acetate, acetone (or strip film), and liquid ether. Kindly correct me if any are wrong, also their quantities.—A. B. (Harrow).

YOU are incorrect in assuming that the average film cement contains acetic acid and ether.

An excellent cement for any type of film may be made by mixing together one part of acetone and one part of amyl (or butyl) acetate, both of which liquids may be obtained from your local branch of Boots the Chemists or from any firm of laboratory chemical suppliers. In this mixture of liquids a quantity of clean scrap celluloid is dissolved until the resulting liquid has the consistency of thin varnish.

Your film cement will be ready for use. Preserved in airtight bottles it will keep indefinitely, although it must be remembered that the cement is highly inflammable.

A Peppermint Still

DO you know where I could get constructional details for building a still for distilling peppermint, and can you supply me with the name and address of a firm manufacturing these stills?—B. G. (Sussex).

EXACTLY what sort of peppermint do you wish to distil? Is it the essential oil of the plant, the plant itself, or any aqueous infusion of the oil? Each of these operations would require a special type of still, but presuming you require to distil the fresh flowers or other parts of the plant, you would require a copper still of at least two-gallon capacity into which steam could be injected. The peppermint oil is volatile in the steam and thus distils over with it, being usually collected in glass receivers, in which it is separated from the water, and redistilled in a small glass still. Such stills could be obtained from Messrs. Philip Humphrey & Co., Ltd., Laboratory Furnishers, Birmingham. You should note, however, that you require an Excise Licence to operate any still legally.

Treating Oak Beams

I WISH to treat the outside oak beams and window sills of a bungalow with a black preservative that will not hide the grain, and which will not discolour the window frames (which will be painted or enamelled white), where the two colours meet. Can you please advise me of a suitable preparation?—S. T. (Wembley).

YOUR best plan is to make up a preservative by dissolving 1 lb. of barium naphthinate in paraffin or white spirit, about one gallon of the latter being required. Apply this liquid to the woodwork in the hot condition (but, of course, bear in mind the fact that the paraffin or white spirit is inflammable). This solution will penetrate the woodwork well and will not stain or hide the grain. Moreover, after the solvent has dried out, the woodwork can be treated in any way desired. Barium naphthinate may be obtained, price about 2s. lb., from Messrs. A. Boak, Roberts & Co., Ltd., Stratford, London, E.15. This material has been given the trade name "Novenate Barium."

Chemicals Required

WHERE can I obtain supplies of deodorised castor oil, ricinoleate of triethanolamine, vitamin F, organic sulphur AK, parachlorobenzoate of soda and stipine. According to the information I have, stipine is a seaweed extract manufactured by a certain maison Gattefosse of Lyon, France, and I wondered if it is manufactured in this country.—G. C. G. (Wilts.).

DEODORISED castor oil (known in the trade as the "Italian" castor oil) may be obtained conveniently from any branch of Boots The Chemists, or, alternatively, from Messrs. A. Boake, Roberts and Co., Ltd., Stratford, London, E.15, from which latter firm also supplies of triethanolamine ricinoleate may be obtained.

Sodium parachlorobenzoate, vitamin F extracts and the various organic sulphurs may be obtained from The British Drug Houses, Ltd., Graham Street, City Road London, N.1. It is possible, also, that Messrs. Harrington Brothers, Ltd., 4 Oliver's Yard, 53a City Road, London, E.C.1, may also be able to supply some of the latter materials, particularly sodium parachlorobenzoate.

We doubt whether you will be able to obtain "Stipine" in this country, but you might try The British Drughouses, Ltd. (Address as above) and, also, Messrs. James Woolley, Sons & Co., Ltd., Victoria Bridge, Manchester. Also Messrs. Reynolds and Branson, Wholesale Chemists, Leeds.

Gas Mask Filters

CAN you tell me what are the contents of the filters in the civilian, civilian duty and service type respirators?

I have built the P.M. master battery clock and am very satisfied with its time keeping. The only trouble experienced was in obtaining the piece of steel from which the pendulum is hung. However, I substituted a piece of copper of the same thickness which answers the purpose admirably.—R. A. (Islington, N.1).

CIVILIAN respirators contain as their active principle a bag or container of coarsely woven material containing a mixture of nut-shell charcoals, permanganate and soda-lime.

The Service respirators contain precisely the same materials but in larger amounts, and, moreover, in these respirators a system of multi-containers is employed. The exact proportions of the various ingredients in the respirator filters has not been made public.

We are pleased to hear that you are so satisfied with the P.M. Master battery clock which you have built according to our instructions, but we do not think you will experience lasting satisfaction by using a piece of strip copper or copper foil in place of the steel suspension spring enjoined in our instructions. We would, therefore, advise you to procure a steel suspension spring of the requisite dimensions. Such an article can be purchased for 2d. or 3d. at any of the clockmakers in the Clerkenwell Road district, E.C.

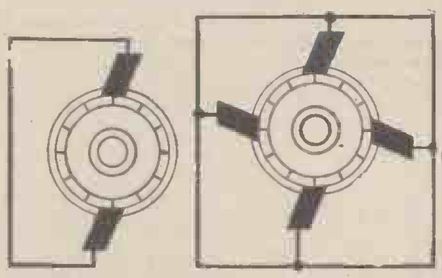
Rocket Detonators

CAN you tell me how the detonations take place in a gas or gasoline fuelled rocket? Is the fuel allowed to enter the combustion chamber in a steady flow, or is the fuel admitted into the tube intermittently and ignited by a sparking plug as it enters ?—J. G. (Glasgow).

SO many varying types of petrol-driven rockets have been proposed and devised by inventors that it is almost impossible to summarise the basic principles of their design. As a rule, however, inventors endeavour to arrange for the rapid burning of a stream of compressed fuel vapour within a small "combustion chamber" situated in the heart of the rocket, the exhaust from this combustion being thrust violently downwards and so setting up a reaction which impels the rocket forward. Sometimes the fuel has been stored at the sides of the rocket; at other times towards the rocket's nose. In nearly every case, however, the fuel vapour is combusted in a continuous flow and not in spasmodic charges.

A CORRECTION

IN the article on "Converting Motor Car Dynamos to A.C. Motors" which appeared in our February issue the illustration Fig. 3 was shown incorrectly. The correct



(Left) The brush connections for a two-pole motor. (Right) Connections for a four-pole motor. In practice carbon brushes are placed radially to the centre and not at an angle

sketch is shown herewith. It should also be pointed out that no definite speed is possible with series-connected motors as this depends entirely on the load for the moment.

Fish Oil

DOES fish oil, such as is obtained from cod or herrings, have any value as a lubricant for high-speed shafting.—E. L. (Wembley).

FISH oils possess no lubricating value whatever. This is because of the fact that, from a chemical standpoint, they are said to be highly "unsaturated," and they will abstract oxygen from the air to form sticky, semi-cold substances which would only impede and gum-up mechanical parts. Some vegetable oils, however, such as castor oil, as you probably know, are highly efficient lubricators.

Pistonless Engine

CAN you give me any information regarding the new pistonless engine invented in U.S.A.—J. K. (Bristol).

NO details concerning the American "pistonless" engine which you mention have reached this country, but it is very possible that the engine in question may comprise some practicable modification of a number of past inventions and suggestions whereby it was proposed to explode charges of gas or vapour in a number of little "pockets" formed in a large circular vessel built around a main shaft. The explosions in these "pockets" or "impeller-chambers" cause a rotary reaction of the circular vessel and so set up its continual revolution. We feel bound to say, however, that the highly experimental engines of this type have never yet been made practicable.

Charcoal Blocks

I WISH to make up some fine bone charcoal into small solid blocks. What medium must I use to bind the charcoal without imparing free burning.—F. Y. (Hounslow).

WITHOUT an adequate bonding press it will be difficult for you to obtain the satisfactory type of compressed charcoal blocks which you require. Such a press would have to exert a pressure of between ½ and ¾ ton per square inch, and, under this pressure, the charcoal would compress without the necessity of incorporating any bonding agent with it. For greater security however, you could, under the above conditions, add 2 per cent. of fire clay with the charcoal.

In the absence of a press, we would suggest that you made experiments in bonding the charcoal powder with Portland cement. Make up a mixture of 8-10 parts of the charcoal powder, 1 part of Portland cement and ¼ part of China or fire clay. Mix these well together and add water so that a stiff paste is formed. Then trowel the paste into wooden moulds, compressing the paste into each mould as tightly as possible. Set the material to dry in a warm oven for two or three days, when useful charcoal blocks should be obtained. These will probably be very brittle, but they will burn completely without giving rise to any objectionable odour.

Calculating Humidity

HOW can I calculate the humidity of a room by the readings on a wet and dry thermometer. I want to run my brooder house at 50 degrees humidity and usually the readings vary 4 to 6 degrees.—C. C. (Wellingborough).

THE wet and dry bulb thermometer measures the relative humidity of the atmosphere, evaporation from the wet bulb causes that thermometer to give a lower reading than the dry bulb thermometer. If the air is dry, the evaporation from the wet bulb will be large. Consequently the temperature difference between the two thermometers will be considerable. If, on the other hand, the air is humid, the evaporation from the wet bulb will be small and thus the temperature difference between the two thermometers will be small. If the air is moisture-saturated, so that no evaporation takes place from the wet bulb, both thermometers will read the same temperature.

In order to express the above-mentioned temperature—difference in terms of relative humidity of the air, a lengthy calculation is necessary, depending upon the fact that

$$\text{Humidity} = \frac{\text{Pressure of aqueous vapour in saturated air at dew point}}{\text{Pressure of aqueous vapour in saturated air at } x^\circ.}$$

Almost invariably, therefore, the determinations of relative humidity are made by referring the temperature-differences of the wet and dry bulb thermometer to a series of Humidity Tables (which were originally compiled by Glaisher). Such tables are readily obtainable and are usually sold as a part of the wet and dry bulb thermometer.

SMALL ELECTRIC FURNACES

Continued from page 280

until cold. The gradual cooling-down which then takes place slowly and steadily, while protected from draughts of cold air by the closed end of the muffle, ensures the steel being reduced to its softest possible condition. After the necessary work has been carried out on it the furnace is again heated up to a bright cherry red, the tool inserted until the same colour is reached, removed and immediately plunged vertically into clean cold water. The condition of the steel should then be glass hard, but too brittle for use, and to give it the necessary strength the temper must be drawn to a point suited to the duty it is intended for. This temper, that is its ultimate hardness, will be indicated by the colour of the oxide film formed on the surface of a portion that has been prepared by removing scale, etc., until the bright metal is exposed. Clean one side of the tool, therefore, with perfectly dry emery paper, free from any trace of oil, and do not even finger the brightened portion or the colour effects will be obscured. After this brightening, the tool is then inserted into the cold furnace, and current switched on, watching closely for the first appearance of any colour effects. In a few minutes a pale yellow colour will appear, followed progressively by dark straw, red, dark blue, light blue, and finally white. The colours will be an indication of the hardness and, therefore, the suitability of the tool for the work it is to perform, yellow being the hardest, and blue the softest.

MAKING MODEL SHIPS IN BOTTLES

Continued from page 278

give a good effect. The land can then be painted green. After painting, a few red-top houses about a ¼ in. square may be added, as these show up well and look quite large from outside the bottle. As each part of the ship is finished it should be painted as it is impossible to paint the ship once it is inside the bottle.

The hull of the ship should be painted black except ⅛ in. from the bottom, which should be painted red. The body, edges of pieces, and top are painted white, and the funnels are red with black tops.

With the ship and the bottle ready it is quite easy to get the ship fitted up inside. Lay the masts down towards the stern, and push the hull into the bottle stern first. As soon as the bow is clear of the neck, hold it down with the rake and pull gently on the mast-stay. As soon as the masts are upright, push the hull further in, and then press down firmly with the rake. A spot of glue placed on the end of a wire, dropped into the hole at the bows, will secure the mast-stay. Allow a few minutes to dry, and then cut off as close as possible to the end of stay, twirling the remainder round with a wire and burying it out of sight on the land side of ship.

The stern piece is the first to be passed in; having first glued the hull part to the underneath part of the stern piece, the needle must not be pushed in too far, or difficulty will be experienced in withdrawing it. The same operation applies to the body, top, funnels, and fo'c'sle piece, which should be fixed in this order.

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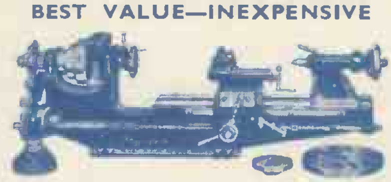

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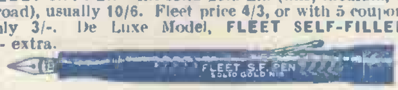

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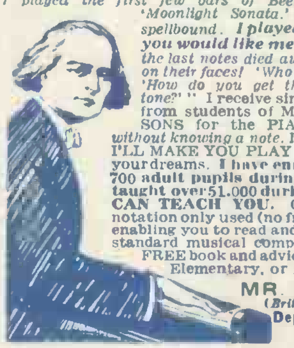

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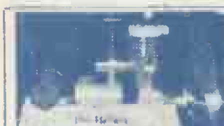

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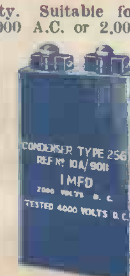

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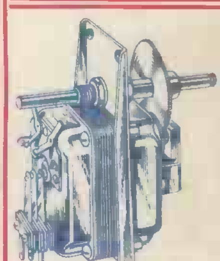

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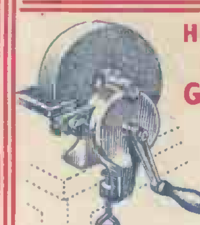

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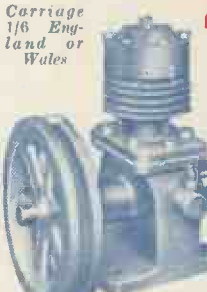

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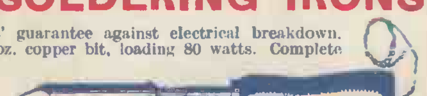

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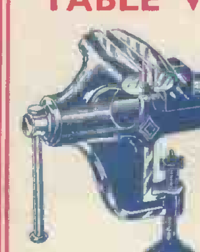

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